THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

APRIL, 1958

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Development of British Welding Standards

A. R. JENKINS: 'Welding Standardization.' *Brit. Welding Jnl.*, 1958, vol. 5, Feb., pp. 50–7.

This paper, which is a modified version of one presented at the Commonwealth Standards Conference held in Delhi in 1957, describes welding-standardization procedure used in the U.K.

The author first gives a brief historical review of the factors which led to the introduction of standards covering welding techniques, quality of work, welding proficiency and inspection tests. Stages involved in the production of B.S. Standards are outlined, and particular reference is made to co-operative procedure between the Institute of Welding, the British Welding Research Association and British Standards Institution, which precedes final publication of a specification.

Some account is given of the general organization set up by the British Standards Institution in connexion with various aspects of its work on welding standards, with illustration of the use of such procedure in setting up individual schedules. The information in the text is supplemented by a diagram showing details of committees of the British Standards Institution working in the respective categories and the standards for which they have been responsible.

The paper includes also a useful table showing British and Commonwealth Standards concerned with welding. In conclusion, attention is drawn to the need for co-ordination, within the Commonwealth, on classification of electrodes, preparation of welds and approval tests for welders.

Catalysts for Hydrogenation Reactions

See abstract on p. 98.

Production, Processing and Uses of Metal Powders

'Proceedings of the 13th Annual Meeting of the Metal Powder Association, 30th April to 1st May, 1957. Vol. I, General Session on Powder Metallurgy.' Published by *Metal Powder Assocn.*, 1957 ; 147 pp.

Abstracts are given below of some papers which are of specific or general interest in relation to nickel-containing powders.

M. EUDIER: 'Activated Sintering', pp. 5–9.

'Activated sintering', as defined by the authors, involves the use of a highly reactive vapour to accelerate sintering of metal particles in a compact. The technique is claimed to confer improved mechanical properties, and is particularly useful as an aid to formation of homogeneous alloys from mixed powders. Conditions necessary for optimum activation are illustrated by reference to iron and iron+silicon powders. More detailed investigation of gas-solid reactions will be necessary to determine the full potential value of the process and the conditions optimum for sintering various types of material.

K. O. COCKBURN, R. J. LOREE and J. B. HAWORTH: 'The Production and Characteristics of Chemically Processed Nickel Powder', pp. 10–24.

The paper opens with a brief history of the development of Sherritt Gordon Mines, Limited. After reference to the utilities and the chemical plant at the Fort Saskatchewan Refinery, the authors outline, with flow sheet, the main features of the Company's ammonia pressure-leach process for nickel extraction. Some account is given of methods for briquetting the powder, and of the sintering process. The paper ends with a discussion of the composition, characteristics and uses of some of the five grades of nickel powder now in regular production. These are standardized according to their respective contents of powders of specified mesh. Reference is made also to a grade of extra-fine powder produced in small quantities only, for specialized use. (Fuller accounts of the process aspect of powder production at the Sherritt Gordon Mines have been given in papers referred to in earlier volumes of *The Nickel Bulletin:* see for example, 1954, vol. 27, Nos. 3 and 6, pp. 40 and 101; 1955, vol. 28, No. 5, p. 83; 1957, vol. 30, No. 9, p. 157.)

In closing, a brief general survey is made of some of the applications of nickel in the powder-metallurgy field, e.g., in permanent magnets, magnetic cores, filters, welding-rod coatings and alkaline batteries.

J. D. SHAW and W. V. KRUPP: 'Current Development in the Rolling of Both Ferrous and Non-Ferrous Powders', pp. 33–41.

A review of techniques currently used to roll metal powders into strip. The authors explain their interest in this process in terms of results which would ensue from the commercial development of strip and sheet made by powder-metallurgy methods. It is presumed that an industrial demand for such products would ensure the expenditure of effort and money which would eventually lead to powder-metallurgical techniques ranking *pari passu* with conventional processes.

The powder-rolling process is examined, stage by stage, from initial introduction of the powder into the rolls, through the sintering stages, to final hot- or cold-rolling. Attention is directed to processing variables which are of importance as affecting the properties of the final product. Tabular data indicate

the properties of nickel and other metal powders suitable for use in rolling to strip, and a comparison is made of the tensile properties of strip prepared from powders and those of strip made by conventional methods. Data on powder-produced strip of nickel, 'Monel', and 18-8 chromium-nickel steels are included.

C. H. SUMP and W. POLLACK: 'Fiber Metallurgy', pp. 42–8.

In 'fibre metallurgy', a technique which is under development by Armour Research Foundation, the starting materials are metal wools or wires, e.g., of steel, nickel-chromium alloys or bronze. The wools or wires are cut to accurate lengths, felted in a liquid medium to achieve the necessary random distribution, and finally bonded by sintering. The resulting fibre materials can be produced with a porosity which, depending on the processing conditions, will vary from 95 per cent. to nearly that of a solid metal. Structures of typical fibre-metal masses are illustrated. It is to be anticipated that, apart from their use as reinforcing bodies, fibre-metal composites will find application as porous media, e.g., in transpiration cooling and filtering.

C. R. TALMAGE: 'Primary Considerations in the Design and Use of Sintered Metal Parts', pp. 49–57.

The paper draws attention to design factors which must be considered if constant and uniform products are to be manufactured by powder metallurgy, to give properties comparable with those of conventionally produced components. The author suggests criteria which may be used by engineers who are specifying sintered products for structural applications.

'Panel Discussion of Presses for Compacting Metal Powders', pp. 58–77; disc., pp. 77–82.

Papers by various authors described presses of American and European design.

L. H. MOTT: 'New Developments in Metal Powder Filters', pp. 83–7.

Filters produced by powder-metallurgy techniques are in some cases ideal for applications involving high pressures and exposure to severe corrosive media and high temperatures. Such filters provide a very fine degree of filtration without bulky overall dimensions, and can be adequately cleaned by back-flushing or by the use of solvents.

This paper reviews techniques used by manufacturers to overcome the difficulty of producing, from powder particles, aggregates which will have uniform pore size (continuous throughout the filter wall), will afford maximum flow capacity, and will give a sharp cut-off point in the degree of filtration. Consideration is first given to the 'no-pressure sintering method', which is applicable in the production of small filters and those of pre-determined shape; secondly, the author discusses the adaptation of conventional press-and-sinter procedure to this branch of powder metallurgy. Mention is made also of the possibility of using slip casting, felting, extrusion and calendering methods.

Binders present one of the major problems associated with filter production, since they must be volatilized from the compact without distortion of the pore size. Standard bonding agents such as the stearates are not applicable to the production of stainless-steel filters, because of the possibility of a carbon pick-up during volatilization of the binder. The author refers to solution of this problem by use of a proprietary material known as 'Cuno Poro-Klean', which, during volatilization of the binder, actually decarburizes the steel almost to the carbon content of an E.L.C. grade. Some experience in the bonding of stainless-steel powders for production of filters is reported. Suggestions are made with regard to criteria which may be used to evaluate filter material: permeability to liquid and gases *vs.* pressure drop, strength, degree of filtration or particle retention, and filter life between reactivation cycles. The quality and reproducibility of each of these criteria are direct functions of the powder and the manufacturing variables.

Among the applications for which metal-powder filters have proved suitable, attention is drawn to the magnetic filters which protect wet-coil Servo valves in aircraft hydraulic systems and to stainless-steel filters used in atomic energy applications. Mention is made also of the possibility of using porous materials as a means of transpiration cooling in high-temperature engines.

G. C. KUCZYNSKI: 'Fundamentals of Powder Metallurgy', pp. 125–30.

The aim of the paper is 'to attempt to acquaint the engineer with our present understanding of the fundamentals of the basic phenomenon in powder metallurgy, namely, that of sintering.' Investigations into the mechanism of sintering indicate that the process involves two largely overlapping stages: (*a*) an early stage (attributed to formation of necks between the particles), which manifests itself by a rapid decrease of electrical resistivity and increase in cohesion, with no appreciable change in density and (*b*) a second stage during which densification of the compact occurs (resulting from elimination of voids). The mechanisms involved in these two processes are theoretically considered, and the conclusions reached are correlated with the results of experimental investigation.

Finally reference is made to a phenomenon which was found to recur constantly during the sintering of multi-component systems. It was observed during the sintering of copper and nickel particles that while necks were formed by a process similar to that occurring in the sintering of particles of the same metal, grooves occurred in the copper particles in the vicinity of the necks. Other experiments

indicated that the grooves always formed in the metal having the lower melting point, and that they were in appearance closely related to the Kirkendall-Hartley effect. The mechanism of this void effect is clarified by brief reference to unpublished work on nickel/copper wire compacts sintered at 1070°C. Photomicrographs of the compacts after sintering for ½ hour and for 12½ hours revealed that the copper diffused into the nickel much faster than the nickel into the copper. As a result, the nickel wires swelled considerably and the copper wires disintegrated, until finally they were consumed by the nickel. The process was accompanied by an appreciable expansion of the compact, which continued until nearly all the copper had diffused into the nickel. At that stage the usual process of sintering began, resulting in normal shrinkage of the compact. It is noted that the initial swelling referred to in the wire experiments is seldom observed in powder compacts, which are usually less closely packed and have room to accommodate the expanding nickel particles.

Other papers contributed to the symposium dealt with chemically precipitated copper powder; diamond products using metal powders; metal powders used in brazing and soldering, and in pyrotechnics and explosives; superfine iron powders; the sintering of iron–copper–carbon compacts; and powder metallurgy in the manufacture of roller chains.

Glossary of Terms Relating to Powders

BRIT. STANDARDS INSTN.: 'Glossary of Terms Relating to Powders.'

B.S. 2955 : 1958; 16 pp. Price 4/6.

The Standard comprises a glossary of selected terms applicable to both metallic and non-metallic powders. 'Powders' are arbitrarily defined as 'discrete particles of dry materials with a maximum dimension of less than 1,000 microns.'

Definitions are arranged in sections covering, respectively, types of powder (classified according to method of production), particle size, particle shape, powder properties and powder processing. Two appendices give information on (*a*) particle mean size and methods for its determination, and (*b*) calculation of Stokes's diameter.

Extrusion of Metals

J. F. W. BISHOP: 'The Theory of Extrusion.'

Metallurgical Reviews, 1957, vol. 2, No. 8, pp. 361–90.

This review may be read in conjunction with a survey of modern extrusion equipment and the mechanics of the process (*ibid.*, 1957, vol. 2, pp. 263–303; see *Nickel Bulletin*, 1958, vol. 31, No. 2, p. 38).

In opening his paper, the present author briefly considers the 'specification requirements' which should be satisfied by an ideal theory of extrusion, and points out the difficulty of evolving such a theory. Reference is then made to the practical aspects of extrusion, since, 'as with the vast majority of metal-forming processes, extrusion in practice is superficially much more a skill than a science. It is a common feature of metal-working processes that practice far outstrips theory, in the sense that the theory frequently gives quantitative expression to what has already been demonstrated practically'. A plea is made for closer contact between theory and practice, as a means of furthering progress.

The review is concerned mainly with the mechanics of extrusion, including consideration of the influence of the major variables inherent in the process, e.g., type of extrusion (direct or inverted), degree of reduction, shape of die, frictional conditions at the die and chamber wall, and nature of the dead metal.

In closing, suggestions are made for future lines of investigation. The review is supported by a *bibliography* of 29 references.

Softening of Cold-Worked Metals by Alternating Strain

See abstract on p. 99.

NICKEL

Nickel-containing Catalysts in Hydrogenation Reactions

'Catalysis, Volume V. Hydrogenation, Oxo-Synthesis, Hydrocracking, Hydrodesulphurization, Hydrogen Isotope Exchange and Related Catalytic Reactions.' Edited by P. H. EMMETT.

Published by *Reinhold Publishing Corpn., New York*; *Chapman and Hall, Ltd., London*, 1957; 542 pp. Price 120/-.

This book is the fifth in a series published with the aim of 'blending discussion of the fundamentals of catalysis with a presentation of a summary of the factual matter in the various catalytic fields'. The subject matter is presented in a way designed to be of interest to those concerned primarily with industrial applications of catalysis as well as to those who are studying the mechanisms by which catalysts function.

Volumes III, *IV* and *V* are intended to cover most of the information available on catalytic hydrogenation. The inter-relation of the three volumes and the scope of the material they contain are summarized in the following excerpt from the preface.

'*Volume III* included principally simple hydrogenation and dehydrogenation reactions in which hydrogen molecules are added to unsaturated bonds or are removed from saturated molecules to form unsaturated molecules. *Volume IV* was devoted almost exclusively to reactions that involved the reduction of carbon monoxide or other carbonaceous material, such as coal or tar, to form hydrocarbons. *Volume V*, the last one dealing with hydrogenation, includes chapters of both types, those concerned with the simple addition of hydrogen and those in which destructive hydrogenation or hydrogenolysis occurs.'

The chapters of *Volume V* are contributed by specialists in the respective fields: all sections include extensive *bibliographies*.

Throughout the book there are numerous references to nickel-containing catalysts of various types.

Intragranular Sub-Structures in Nickel

P. FELTHAM: 'Intragranular Sub-Structures in High-Purity Nickel.'

Jnl. Inst. Metals, 1957–58, vol. 86, Jan., pp. 237–40.

Recent work by Michell and colleagues on the release of strain energy stored in deformed nickel shows that the energy is rapidly released on annealing at temperatures above about 500°C., but that it does not fall below a certain level characteristic of the annealing temperature. In comparison with the residual energy preserved after even prolonged annealing at 500°C., the corresponding energy at 800°C. is extremely small. It thus appears probable that the metal is almost fully polygonized above 800°C. It was considered likely that a study of sub-structures developed in nickel during isothermal annealing in the range 700°–900°C. would provide insight into the processes of polygonization, and this report describes work along these lines. Since X-ray and etching techniques appear to be the most satisfactory means of examining the distribution of dislocations in metals, and because the two techniques are largely complementary, both were employed in this research. Most attention was given to the etching method, the conditions for which are described below:

'The method adopted, which was rapid and entirely satisfactory, is as follows. The sample is placed in a Petri dish into which concentrated HNO_3 is gently poured until the metallographically polished upper surface of the specimen is submerged to a depth of about 1½ mm. After a few seconds the specimen surface is seen to darken, and slightly discoloured grains may be observed. At this stage about 1 c.c. of concentrated HCl is slowly poured, viâ a glass rod or by means of a burette with its tip just below the liquid level, onto the centre of the specimen surface. The latter immediately assumes a mirror-like appearance. It may then be removed from the etchant, dropped into a large quantity of water, removed, rinsed with alcohol, and dried in a stream of dry air. Occasionally the whole etching process had to be repeated because effects due to mechanical polishing had not been entirely obliterated, even by the deep etch produced by this method.'

The sub-structures of some nickel specimens developed by the method described are shown in this paper.

In specimens annealed at 850°–900°C., the formation of a cell structure with mesh size of the order of 20μ is observed; the density of etch pits delineating it is approximately 3×10^5/cm.^{2}. A regular block structure of edge dislocations, with a characteristic inter-dislocation spacing of 2–3μ and a corresponding dislocation density of about 10^7/cm.^{2}, exists side by side with the cell structure. The inclination between adjacent blocks defined by edge dislocations, evaluated on the assumption that each etch pit of the block structure represents one edge dislocation, was found to be approximately ½′, in agreement with estimates obtained from the angular spread of X-ray-diffraction arcs.

Softening of Cold-Worked Nickel by Alternating Strain

W. A. WOOD and R. L. SEGALL: 'Softening of Cold-Worked Nickel by Alternating Strain.'

Jnl. Inst. Metals, 1957–58, vol. 86, Jan., pp. 225–8.

Recent work has shown that alternating plastic strain, unlike uni-directional or static strain, need not cause strain-hardening. The plastic strain, after a few cycles, becomes reversible and non-hardening. It therefore follows that alternating and uni-directional deformation build up in different ways the internal stresses responsible for strain-hardening. Uni-directional deformation, since normally it always strain-hardens, must build up the stresses progressively and allow the metal to store them in the lattice indefinitely: for example, by creating the stress fields of immobilized dislocations postulated by the Taylor-Mott theories. Alternating deformation apparently allows the metal to relax excessive stress fields as fast as they form.

The authors point out that if this inference is correct, it throws doubt on views of fatigue failure, typified by Orowan's theory, which assume that alternating strain always progressively builds up internal stresses and that it causes fatigue cracks by building up local stresses as large as the fracture strength of the metal. Further tests, to determine the validity of this inference, are therefore of interest, and one possible method is to apply alternating plastic deformation to a metal which is already in a strain-hardened state. Softening of the metal would confirm that the alternating strain tends to relax excessive internal stresses rather than build them up.

The authors make reference to literature which indicates that such softening does occur in cold-worked metals under reversed strain. They then report experimental work in which specimens of cold-worked metals (copper, nickel, aluminium) were subjected to alternating torsion tests, with measurement of the proof stresses required to impose successive reversals of plastic strain. It was found that 'further strain-hardening occurs as the first reversals are applied, but that this hardening soon reaches a peak, which is followed by softening. The latter is the more marked as the preliminary cold working is heavier, and the plastic amplitude smaller.' It is postulated that stress relaxation would occur at the surface of a specimen because the fine to-and-fro slip movements in alternating strain may build up slip bands having notch-like contours.

Grain-Boundary Self-Diffusion of Nickel

W. R. UPTHEGROVE and M. J. SINNOTT: 'Grain-Boundary Self-Diffusion of Nickel.'

Trans. Amer. Soc. Metals, 1957, vol. 50, *Preprint* 52; 30 pp.

The diffusion of nickel-63 into controlled-orientation

bicrystal grain boundaries of nickel, in the temperature range 700°–1100°C. was studied, using autoradiographic techniques. The ratio of the grain-boundary diffusion coefficient to the lattice-diffusion coefficient is shown to vary from 10^3 to 10^7, depending on the grain-boundary angle and the temperature of diffusion; the largest ratios were obtained in boundaries of large misfit, diffused at low temperatures. The activation energy for grain-boundary self-diffusion was found to be 26 k-cal per gram mole for the one degree of freedom boundaries between 20° and 70°. Outside these limits it appears to increase rapidly with decreasing misfit, to 65·9 k-cal per gram mole, the value for lattice self-diffusion.

Effect of Pressure in Diffusion of Copper and Nickel

R. S. BARNES and D. J. MAZEY: 'The Effect of Pressure upon Void Formation in Diffusion Couples.'

Acta Metallurgica, 1958, vol. 6, Jan., pp. 3–7.

It has been shown that formation of voids during interdiffusion of two different metals is a general phenomenon when both are face-centred-cubic types. It is believed that these voids result from the supersaturation of vacancies produced by the unequal diffusion flow of atoms (first reported by SMIGELSKAS and KIRKENDALL). The present authors review the principal reasons for concluding that the voids are formed by the precipitation of vacancies.

The experimental work consisted in diffusion of sandwiches of copper and nickel under various hydrostatic pressures. It was observed that pressure reduces the number of voids present: above a critical pressure no voids were found. Further, voids previously formed by annealing *in vacuo* were eliminated by applying pressure during subsequent heat-treatment, but it was observed that the critical pressure required for removal of voids was greater than that needed to prevent their initial formation. It is concluded that the vacancy supersaturation is about 1 per cent. and that the voids nucleate heterogeneously upon nuclei (about 10^{-5} cm. in size) which are included in the weld between the two metals. No evidence was found of any change in the diffusion coefficient of copper into nickel as the result of pressure.

Microwave Resonance in Nickel

G. S. BARLOW and K. G. STANDLEY: 'Microwave Resonance in Nickel at 35 Gc/s (kMc/s).'

Proc. Physical Soc., 1958, vol. 71, Jan. 1, pp. 45–8.

Report of study of microwave resonance absorption at a wavelength of 0·86 cm., in a single crystal of nickel, in polycrystalline nickel, and in nickel-copper and nickel-manganese alloys. Measurements were made within the temperature range 20°–200°C., and the main object of the investigation was to determine the spectroscopic splitting factor g and, in the case of the single crystal, the anisotropy constants K_1, K_2.

Influence of Nickel on Gushing Tendencies of Beers

P. P. GRAY and I. STONE: 'Metal-Induced Wildness in Beers.'

Proc. Amer. Soc. Brewing Chemists, 1956, pp. 83–108.

By means of a rapid shake test and an extended cold-storage test experimentally developed, the authors determined the influence of 41 metals on the gushing tendencies of beers after addition of salts containing the molar equivalent of 2 and 10 p.p.m. of iron. The metals are classified, in terms of their relative activity, into four groups. Nickel was found to be active, but gushing was suppressed by addition of 400 p.p.m. of a chelating agent, the cadmium disodium salt of ethylenediaminetetraacetic acid (EDTA). For details of results see *Chemical Abstracts*, 1957, vol. 51, Oct. 25, p. 15,882.

Production, Processing and uses of Nickel Powders

See abstract on p. 96.

Sintered Filters of Nickel-containing Materials

See abstract on p. 113: see also p. 97.

Nickel Equipment used in Deodorization of Vegetable Oil

'Nickel Equipment used in Deodorization of Vegetable Oil.'

Chemical Processing, 1958, vol. 4, Feb., p. 8.

Deodorization, an essential stage in the processing of most vegetable oils intended for use in food products, is usually carried out by steam-distilling the oil under vacuum, to drive off the volatile constituents responsible for the undesirable flavours and odours. This article describes the continuous process employed by Southern Oil Company, Limited, Manchester.

The deodorizer consists of a cylindrical shell about 28ft. (8·5 m.) high, in which a vacuum of about 6 mm. is maintained. The shell is fitted with five trays, one above the other. Every half hour a batch of feed stock is automatically released into the top tray, heated by a steam coil to about 350°F. (175°C.), and then passed into a second tray, where it is further heated to about 480°F. (250°C.) by means of a 'Dowtherm'-heated coil. The oil is then dropped into the two deodorizing trays, where it is treated with stripping steam and finally passes to the bottom tray, to be cooled before being discharged.

Mild steel was formerly used for the deodorization equipment, but, like many other metals, it has the disadvantage of acting as a pro-oxidant when in contact with fat, thus seriously impairing the keeping qualities of the product. The Company has overcome this difficulty by ensuring that all components of the equipment which come into contact with the oil are made either of solid nickel or nickel-clad steel. The use of nickel, from which there is no measurable pick-up of metal by the oil, has led to

efficient deodorization, and the oil is further protected from deterioration by holding it at the high temperatures involved for only a minimum of time, and by avoiding refluxing.

ELECTRODEPOSITION AND OTHER COATING METHODS

Plating of Nickel and Nickel Alloys

W. W. SELLERS and C. B. SANBORN: 'Electroplating on Nickel and Nickel Alloys.'
44th Ann. Tech. Proceedings, Amer. Electroplaters' Soc., 1957, pp. 36–41.

By courtesy of The American Electroplaters' Society we are able to publish this extended abstract of a paper recently presented to the Society.

The paper may be regarded as a miniature 'handbook', being based on information from published literature and unpublished data collected, over a considerable period, in the files of The International Nickel Company. The basis materials to which the paper refers are shown in Table I, pp. 102–3.

After brief discussion of the various purposes for which an electrodeposited coating may be required on nickel or nickel alloys, the authors tabulate the compositions of dull nickel-plating baths commercially used, and the properties typical of deposits made from them: see Table II, p. 104.

The influence of modifications in composition, within the limits given in the table, is discussed, with appropriate reference to the literature.

Attention is drawn to the omission of bright-nickel electrolytes from the table. Such solutions are usually proprietary, and the authors consider that it is not their prerogative to discuss the relative characteristics of such baths other than in brief general terms. The Watts solution constitutes the base for bright-plating electrolytes, and individual characteristics are maintained by incorporating combinations of organic and/or inorganic addition agents, to produce or control brightness, levelling, and stress in the deposits.

Mechanical preparation of the metal which is to be plated is discussed only in general terms, but attention is directed to easily available literature in which precise recommendations are made. The stages in degreasing and cleaning are listed, again with references to sources in which full details of recommended practice are given. The final stage in preparation for plating is that of activation, and correct procedure at that stage is a vital factor in ensuring adhesion of the coating to the basis metal. As a guide, details are given (see Table III, p. 105) of activation cycles which have been found suitable for use in preparation of nickel and nickel alloys for plating. The procedure(s) optimum for the respective basis metals are indicated in the final column of Table I, p. 103.

Bright-Nickel-Plating Process: 'Efco-Udylite No. 66'

'Efco-Udylite Bright Nickel-Plating Process No. 66.'
Electroplating and Metal Finishing, 1958, vol. 11, Feb., pp. 62–3.

The main advantage claimed for the new process, by comparison with others of the 'Efco-Udylite' group, is the high ductility achieved in the deposit. Since none of the organic addition agents used are appreciably absorbed by active carbon, the solution can be continuously regenerated through a carbon-packed filter, and ductility is maintained at its initial high value without need for the purification treatments essential with other bright solutions. In nickel/chromium deposits in which the nickel underlay is produced from the No. 66 solution ductility increases with time, particularly on steel components. Other benefits of the new solution are the high permissible current densities at which it can be operated (up to 100 amp./sq. ft.; 10·8 amp./dm.^{2}), its levelling power, the brightness of the deposit obtained, and the suitability of the nickel coating for overplating with chromium. The electrolyte used contains, in addition to nickel sulphate, nickel chloride, boric acid and sodium fluoborate, specified amounts of three types of brightener, the functions of which are discussed. The solution (pH 3·5 electrometric) is air-agitated, and is operated at 140°–160°F. (60°–70°C.).

It is stated that most Watts-type nickel solutions can be converted to the No. 66, which is suitable for plating steel, cast iron, copper and brass. It is not recommended, however, for use on copper-plated zinc-alloy components, due to its susceptibility to zinc contamination.

Electroless Nickel Plating: 'Niphos' Process

'New Chemical Process Plates Resistant Nickel.'
Chemical Engineering, 1958, vol. 65, Jan. 13, pp. 172, 174.

In the field of electroless plating two processes of practical significance have emerged: the 'Kanigen' process, which is now well established, and the 'Niphos' process, developed by Tube Reducing Corporation, New York, which is relatively new. This article describes the latter method, considering its advantages and limitations in comparison with the 'Kanigen' plating.

The 'Niphos' process involves depositing (by painting, dipping or spraying) a paste of nickel oxide, diammonium phosphate and water onto a well-cleaned basis-metal surface. This paste is allowed to dry under atmospheric conditions and the coated parts are then heated in a dry-hydrogen controlled-atmosphere furnace, at temperatures of the order of 1650°F. (900°C.). Nickel separates from the oxide, fuses, and alloys with the basis metal, to form a coating which contains about 98 per cent. of nickel and 2 per cent. of phosphorus. Usually the coating is about one mil thick, but thicker deposits can be achieved by repetition of the process. (Brief notes, for purposes of comparison, are given on the 'Kanigen' technique.)

Coatings obtained by both processes are claimed to

TABLE

COMPOSITIONS OF TYPICAL HIGH-NICKEL ALLOY WITH KE

(See abstract p. 101)

Alloy	Nickel (+ Cobalt) %	Copper %	Chromium %	Iron %	Aluminium %	Silic %
'Duranickel'	94·00	0·05	—	0·35	4·50	0·
'Duranickel R'	94·00	0·05	—	0·35	4·00	0·
'Incoloy T'	32·00	0·25	20·00	46·00	—	0·
'Incoloy 901'	40·00	0·05	13·00	35·00	—	0·
'Inconel' (Regular)	77·00	0·25	15·00	7·00	—	0·
'Inconel W'	74·00	0·05	15·00	7·00	0·60	0·
'Inconel X'	73·00	0·05	15·00	7·00	0·75	0·
'Invar' (Regular)	35·5	—	—	Balance	—	–
'Invar' (Free-Cutting) ..	36·0	—	—	Balance	—	0·
'Monel' (Regular)	67·0	30·00	—	1·40	—	0·
'K Monel'	66·00	29·00	—	1·00	2·75	0·
'R Monel'	67·00	30·00	—	1·40	—	0·
'KR Monel'	66·00	29·00	—	1·00	2·75	0·
'A' Nickel	99·00	0·10	—	0·15	—	0·
'D' Nickel	94·00	0·05	—	0·05	—	0·
Electro-Nickel	99·90	—	—	—	—	-
Low-carbon Nickel	99·00	0·10	—	0·15	—	0·
'Nimonic 75'	75·00	0·35	20·00	1·75	0·25	0·
'Nimonic 80A'	70·00	—	20·00	2·50	1·00	0·
'Ni-Span C'	42·00	0·10	5·25	49·00	0·50	0·
'Ni-Resist' Type I	14·00	6·0	2·00	Balance	—	1·
'Ni-Resist' Type II	20·00	—	2·00	Balance	—	2·
'Ni-Resist' Type III	30·00	—	3·00	Balance	—	1·
'Ni-Resist' Type IV	31·00	—	5·00	Balance	—	5·
'Ni-Resist' Type V	35·00	0·5	1·50	Balance	—	1·
Stainless Steel (18-8 Series: Type 304)	8·00	—	18·00	Balance	—	0·
'Uniloy' No. 1	8·00	—	18·00	Balance	—	
'Uniloy' No. 2	12·00	—	21·00	Balance	—	

TABLE

ALLOY WITH KEY TO ACTIVATION TREATMENTS

(See abstr... on p. 101)

minium %	Silicon %	Titanium %	Manganese %	Carbon %	Sulphur %	Other Elements %	Activation Treatment (see Table III)
·50	0·50	0·50	0·30	0·25	0·005	—	1
·00	0·50	0·50	0·30	0·25	0·005	—	1
—	0·50	1·00	0·75	0·05	0·008	—	6
—	0·25	2·40	0·45	0·05	0·009	Mo 6·0	8
—	0·25	—	0·25	0·06	0·007	—	6
·60	0·25	2·50	0·50	0·04	0·007	—	7
·75	0·40	2·50	0·50	0·05	0·007	Nb and Ta 0·90	7
—	—	—	0·42	0·18	—	—	2
—	0·20	—	0·35	0·12	—	Se 0·20	6
—	0·10	—	1·00	0·15	0·01	—	3
·75	0·50	—	0·75	0·15	0·005	—	3
—	0·50	—	1·00	0·15	0·035	—	3
·75	0·50	—	0·75	0·25	0·005	—	3
—	0·05	—	0·25	0·05	0·005	—	1
—	0·05	—	4·75	0·10	0·005	—	5, 6, 7
—	—	—	—	—	—	—	1, 5
—	0·05	—	0·25	0·01	0·005	—	1
·25	0·50	0·35	0·75	0·10	0·008	—	6
·00	0·75	2·50	0·75	0·05	—	Co 1·75	6
·50	0·50	2·00	0·25	0·05	0·008	—	1
—	1·50	—	1·00	3·00	—	—	4
—	2·00	—	1·20	3·00	—	—	1
—	1·50	—	0·60	2·75	—	—	1
—	5·50	—	0·60	2·60	—	—	1
—	1·50	—	0·60	2·40	—	—	1
—	0·75	—	0·70	0·08	—	—	6
—	—	—	—	0·20	—	—	6
—	—	—	—	0·20	—	—	6

TABLE II
REVIEW OF VARIOUS TYPES OF NICKEL BATHS

(*See abstract on p. 101.*)

Type of Solution	Nominal Composition			pH	Temperature		Normal C.D.		Stress p.s.i. $\times 10^{-3}$	Typical Mechanical Properties		
	oz./ U.S. gal.	oz./ Imp. gal.	g./L.		°F.	°C.	amp./ft.²	amp./dm.²		Hardness (Vickers)	Elongn. % in 2 in. (50 mm.)	U.T.S. p.s.i. 10^{-3}
Watts—Low-pH				1·5-4·0	115-140	45-60	25-100	2·5-11	20	140-160	30	55
Nickel Sulphate ..	44	53	330									
Nickel Chloride ..	6	7	45									
Boric Acid	5	6	37									
Watts—High-pH				4·0-6·0	115-150	45-65	20-100	2-11	20-70	150-205	20-30	65
Nickel Sulphate ..	32	38	240									
Nickel Chloride ..	6	7	45									
Boric Acid	4	5	30									
Chloride				2	130-150	55-65	25-100	2·5-11	40	230-240	20	98·9
Nickel Chloride ..	40	48	300									
Boric Acid	4	5	30									
Chloride-Sulphate				1·5	115	45	100	11	31	150-240	20	75
Nickel Sulphate ..	26·7	32	200									
Nickel Chloride ..	23	28	171									
Boric Acid	5·3	6	40									
Hard Nickel				5·6-5·9	110-140	45-60	25-50	2·5-5·5	33	380-480	6	157
Nickel Sulphate ..	24	29	180									
Ammonium Chloride	3·3	4	25									
Boric Acid	4	5	30									
Basic Sulphamate				3-5	100-140	40-60	65-75	7-8	6	140-155	14-31	60
Nickel Sulphamate ..	60	72	450									
Boric Acid	4	5	30									
Sulphamate +Cl(−)				3·5-4·2	75-160	25-70	20-140	2-15	13-18	200-250	5	94-108
Nickel Sulphamate ..	40	48	300									
Nickel Chloride ..	4	5	30									
Boric Acid	4	5	30									
Fluoborate				2·7-3·5	130	55	50	5·5	15	130	32	56
Ni Fluoborate ..	40	48	300									
Boric Acid	4	5	30									

TABLE III

Activating Treatments for Nickel-containing Materials

(*See abstract on p. 101*)

Pre-Treatment No.	Activation Bath	Operating Conditions
(1)	25 wt. % Sulphuric Acid (66° Bé acid) — 22 oz./U.S. gal. / 26 oz./Imp. gal. / 165 g./L.	Tank: Glass, lead-, rubber- (natural or synthetic) or plastic-lined Temperature: 70°-80°F. (21°-25°C.) Electrodes: Chemical lead Operation: Anodic at 20 amp./ft.² (2·2 amp./dm.²) for 10 min. Anodic at 200 amp./ft.² (22 amp./dm.²) for 2 min. Cathodic for 2-3 sec. Rinse before placing in plating solution
(2)	As for (1)	Tank, temperature and electrodes as for (1) Operation: Anodic at 200 amp./ft.² (22 amp./dm.²) for 3 min. after onset of passivity
(3)	As for (1)	Tank, temperature and electrodes as for (1) Operation: Anodic at 200 amp./ft.² (22 amp./dm.²) for 5 min. after onset of passivity
(4)	As for (1)	Tank, temperature and electrodes as for (1) Operation: Anodic at 100 amp./ft.² (11 amp./dm.²) for 1 min., then 200 amp./ft.² (22 amp./dm.²) for 4 min.
(5)	Low-pH Watts-type or Nickel-Chloride Solution	Tank: Glass or any material approved by supplier for handling nickel solutions Temperature: Usually 130°-140°F. (55°-60°C.) but temperatures both higher and lower may be used if other conditions permit Electrodes: Whatever is being used for regular nickel anodes Operation: Anodic at 10-20 amp./ft.² (1·1-2·2 amp./dm.²) for 10 min., then reverse current and plate under normal conditions
(6)	Acid Nickel-Chloride Solution $NiCl_2.6H_2O$ — 32 oz./U.S. gal. / 38 oz./Imp. gal. / 240 g./L. Hydrochloric Acid — 11 fl. oz./U.S. gal. / 13 fl. oz./Imp. gal. / 86 g./L.	Tank: Glass, rubber- (natural or synthetic) or plastic-lined Temperature: 70°-80°F. (20°-25°C.) Electrodes: Nickel (except carbon-containing) Operation: Anodic for 2 min., then cathodic for 6 min., both at 30 amp./ft.² (3·3 amp./dm.²) (Separate tanks may be used for the two phases of this treatment if desired) Introduce into plating bath without rinsing
(7)	As for (6)	All conditions as for (6), except that anodic treatment is for only 15 sec.
(8)	50% Hydrofluoric Acid (by weight)	Temperature: Room Operation: Dip for 10 sec.

be practically pore-free, and Tube Reducing Corporation claim also that 'Niphos' coatings are resistant to deterioration at temperatures up to 1150°F. (620°C.) and that they can be bent through an angle of 180° without flaking or peeling off. The hardness values are not as high as those of 'Kanigen' deposits, but a higher ductility is claimed. The 'Niphos' coatings are satisfactorily machinable. Both types are resistant to corrosion by media which do not attack nickel, but are not recommended for service in contact with molten metals, concentrated sulphuric acid, cupric and ferric chlorides, hypochlorites, or silver nitrate.

Among the problems encountered in connexion with the 'Niphos' process are difficulty in welding the coated parts (due to the high phosphorus content), and the high temperature required in the firing stage.

It is stated that on an economic basis the 'Niphos' process is competitive with 'Kanigen' plating. As an example of its potential use, reference is made to steam-heater coils which are now being coated for an oil tanker.

NON-FERROUS ALLOYS

Nickel-Gallium Alloys: Constitution

W. B. PEARSON and D. M. RIMEK: 'Constitution of Nickel-Gallium Alloys in the Region 0-35 Atomic % Gallium.'

Canad. Jnl. Physics, 1957, vol. 35, Oct., pp. 1228-34.

Detailed description of work which led to a revision of the equilibrium diagram of this system. The authors report a newly-discovered Ni_3Ga superlattice, which forms peritectically at 1210°C. Attention is directed to a very close resemblance between the nickel-aluminium and nickel-gallium alloy systems, in the nickel-rich region.

Zinc-Iron-Nickel Alloys: Constitution

G. V. RAYNOR and J. D. NODEN: 'A Note on the Zinc-Rich Alloys of the System Zinc-Iron-Nickel.'

Jnl. Inst. Metals, 1957-58, vol. 86, Feb., pp. 269-71.

The authors draw attention to some observations which have been made on the compositions and structures of aluminium-rich intermetallic compounds formed by aluminium and transitional metals of the First Long Period of the Periodic Table. Particular interest attaches to the existence, in the aluminium-iron-nickel system, of a ternary compound based on the composition $FeNiAl_9$, which is isomorphous with Co_2Al_9. The ternary compound has an extensive solid solubility for nickel; along the aluminium-rich phase boundary, across which equilibrium with the aluminium-rich solution is established, nickel replaces iron in such a way that the composition may be represented as $Fe_{1-x}Ni_{1+x}Al_9$. The solubility of nickel in Co_2Al_9 is analogously extensive, and experiments suggest that an atom of iron and an atom of nickel together behave like two atoms of cobalt in these compounds.

The work reported in this paper was carried out as part of an investigation designed to establish whether that type of behaviour is exhibited in ternary systems based on metals other than aluminium. The conclusions reached are given below:

'A limited survey of the zinc-rich equilibria in the system zinc-iron-nickel, by metallographic and X-ray methods, shows that a ternary compound *T* (ZnFeNi) is formed and enters into equilibrium with the zinc-rich solid solution. Analysis of extracted crystals indicates a composition represented by the formula $Fe_6Ni_5Zn_{89}$. In composition this appears to be analogous to the binary zinc-cobalt δ_1 phase, the zinc-rich limit of which may be represented as $Co_{11}Zn_{89}$. The two phases do not seem to be isomorphous, but the compositional correspondence suggests that, as in aluminium-rich alloys, an atom of iron and an atom of nickel may together behave as two atoms of cobalt.'

Phase Changes in Films of NiO-Cr_2O_3 and NiO-Al_2O_3

D. V. IGNATOV: 'Electronographic Investigations of Phase Changes in Thin Layers of Metals and Oxides.'

Kristallografiya, 1957, vol. 2, pp. 484-8.

Study, by electron diffraction, of phase transformations in thin films of Al, Fe-Al, NiO-Cr_2O_3 and NiO-Al_2O_3 resulting from exposure in air to temperatures ranging from room to 1300°C. At 400° and 500°C. the NiO-Cr_2O_3 mixture consisted of αCr_2O_3+ NiO; at 600°C. traces of $NiCr_2O_4$ appeared and gradually increased with temperature, until at 800°C. the film consisted predominantly of $NiCr_2O_4$.

Details of the other results are given in *Chemical Abstracts*, 1957, vol. 51, Nov. 25, p. 17,279.

Microwave Resonance in Nickel Alloys

See abstract on p. 100.

Effect of Pressure in Diffusion of Copper and Nickel

See abstract on p. 100.

Sintered Filters of Nickel-containing Materials

See abstract on p. 113.

Nickel-containing Materials in an Oil Refinery

See abstract on p. 114.

CAST IRON

Nickel-containing Cast Irons in Turbo-Charged Diesel Engines

F. G. SEFING: 'Metallurgy Makes the Difference.'

Diesel Power, 1957, Nov.

Reprint issued by INTERNATIONAL NICKEL CO., INC.

Turbo-charging has been a most significant development in contributing to increased efficiency in marine

diesel engines: a suitable turbo-charger can raise the power output of an engine by 25–120 per cent. Increased power ratings up to about 30 per cent. can be achieved without the development of major mechanical or thermal problems, but use of turbo-chargers of higher capacity involves design and constructional modifications, due to the higher temperatures of the gases handled and the greater mechanical stresses to which pistons, cylinder heads and other components are subjected.

This paper reviews the problems resulting from turbo-charging, and indicates grades of cast iron having strength and heat-resistance which recommend them for service in engineering parts of turbo-charged diesel engines of various types. The components discussed are pistons, cylinders, piston rings, cylinder heads, valves, valve seats, and guides, and exhaust manifolds.

Information in the text is supplemented by tabular data on the physical and mechanical properties of S.G. iron, various types of 'Ni-Resist' and 'S.G. Ni-Resist'.

CONSTRUCTIONAL STEELS

Micro-Constituents in Steel: Extraction and Examination

K. W. ANDREWS and H. HUGHES: 'Micro-Constituents in Steels: Their Electrolytic Isolation and X-Ray Study.'

Iron and Steel, 1958, vol. 31, Feb., pp. 43–50.

This article records results of research carried out over a considerable period in the laboratories of The United Steel Companies, Limited. It is based on a paper presented by the senior author at a Conference of Industrial Applications of X-ray Analysis, held at Denver, U.S.A., in August 1957.

It is pointed out that, apart from the possible formation of eutectics and eutectoids or other aggregates of phases, the alloy elements in steel may influence constitution in two primary ways: by solid-solution formation, and by formation of carbides or compounds. These carbides, nitrides and intermetallic compounds can have an important influence on the properties of the material. In the course of research into the constitution of steels, the authors have therefore increasingly employed methods for separating the micro-constituents, for examination by X-rays or other techniques.

The work described in this paper deals with the three essential stages of such examination:

(1) Isolation of the particles (electrolytic methods only are described).

(2) Examination of the particles, in particular by X-ray analysis, in order to identify them and to provide information on particle-size or -shape, solid-solution effects, etc.

(3) Use of the results of such examination in interpreting the properties and behaviour of steels.

(1) After brief comment on some of the electrolytic cells and extraction techniques which have been referred to in the literature, the authors describe two cells which they have found to be capable of giving separations as efficiently, as completely and as quickly as possible, with the simplest possible apparatus and operating techniques.

In the course of the work, many electrolytes have been considered, but the final result has been to standardize on a small number of solutions, used in conjunction with one or other of two types of cell:

(*a*) An enclosed cell in which the electrolyte is out of contact with air and in which nitrogen or other inert gas is used to drive out air from the apparatus and solutions, thus preventing oxidation or decomposition of carbides.

(*b*) An open cell, set up in a glass beaker, and employing a porous ceramic pot (or other device) to separate the cathode from the anode.

Detailed drawings of both types of cell are shown and their operation is described. An associated table gives the compositions of six electrolytes which have been adopted as optimum for specific extractions, with notes on their respective advantages and disadvantages, the types of steel for which they are used, and other relevant information.

(2) In considering X-ray techniques, the authors comment on the usefulness of standard cylindrical powder cameras for accurate study of lattice parameters, but urge that for certain types of work a focusing camera has advantages. It gives a lower background and sharper lines, with considerably better separation, and is therefore valuable when two or more phases are found together and when identification is the primary objective. It is noted that in some cases as many as six constituents have been identified in one sample, also that smaller amounts of constituents are thus detectable. A figure illustrating the paper shows eight typical powder-diffraction patterns of carbides and other phases separated from steels.

A review is made of the main types of information which can be obtained from X-ray-diffraction examination of extracted residues (with or without supplementary data).

(3) In the final section of the paper information of the type described is considered in relation to its significance in determining the constitution (and/or properties) of the materials from which extracted residues come. The value of the technique is demonstrated by reference to specific cases in which it has furnished information which would not otherwise have been readily obtainable. The examples quoted relate to:

Observation of ε carbide in the early stages of tempering of martensite.

Study of carbides in low-carbon steels, in connexion with investigation of strain-ageing.

Sigma formation in 25-15 chromium-nickel steel, as a function of composition, with special reference to silicon and carbon.

Determination of the constitution and optimum titanium content in a chromium-molybdenum-titanium steel developed for steam-power plant.

Carbide reactions and other changes in a low-alloy chromium-molybdenum heat-resisting steel.

Transformations in Nickel-Alloy-Steel Weld Metal

E. F. NIPPES and E. C. NELSON: 'Continuous-Cooling Transformation Characteristics of Three Types of Weld Metal.'

Welding Jnl., 1958, vol. 37, Jan., pp. 30S-6S.

Using a high-speed dilatometer covering a range of cooling rates sufficiently wide to include all the important sub-critical transformations occurring during continuous cooling of low-alloy and high-alloy weld metals, the authors studied transformations in three types of commercial weld metal. The three electrodes used conformed to MIL-E-986: the deposited weld-metal pads were, respectively, of the compositions given in the table below.

Continuous-cooling transformation diagrams are shown for the three types of weld metal, and differences in transformational behaviour and microstructures are discussed in terms of alloy content.

The 'Steelmet' Powder-Metallurgy Process

'Sintered Metals Approach Properties of Wrought Alloys.'

Iron Age, 1958, vol. 181, Jan. 23, pp. 88-90.

See also *Chemical and Engineering News*, 1958, vol. 36, Jan. 13, p. 45.

Until recently difficulty has been encountered in achieving, in powder-metallurgy parts, a density sufficiently high to ensure mechanical properties comparable with those of conventionally produced components. These articles give brief notes on the 'Steelmet' process, one of the methods developed for production of compact powder-metallurgy parts of high density. The information, taken from a paper by F. R. HENSEL, presented to a recent meeting of the American Association for the Advancement of Science, is based on a method developed by P. R. Mallory and Company.

It is claimed that, by this technique, alloys of iron base, processed by a single pressing and sintering operation, can be produced with a density 95 per cent. of the theoretical density of the material. Tensile strengths of the 'Steelmet' products range from 42,000 to 200,000 p.s.i. (18·75 to 89·5 t.s.i.: 29·5 to 140·5 kg./mm.^{2}). Elongation of 15-30 per cent. can be obtained in the finished product.

The process is claimed to be suitable for the manufacture of components such as gears, cams, levers and ratchets and other precision parts which now usually involve machining. Details of production methods have not yet been released, but it is stated that the process 'has been developed primarily by modifying the chemical and physical properties of the starting materials, rather than by changing the later processing.'

Various ferrous materials (listed in the article) are being experimentally developed, and four steels are already in pilot-plant production.

Production, Processing and Uses of Metal Powders

See abstract on p. 96.

Pickling of Steels

W. BULLOUGH: 'Pickling, De-Scaling and De-Rusting of Steels.'

Metallurgical Reviews, 1957, vol. 2, No. 8, pp. 391-406.

A review, supported by a *bibliography* of 50 items.

An introductory section dealing briefly with the nature of scaling and the theory of pickling by acid media is followed by discussion of some recent developments in methods of pickling, and present-day techniques. Major sections of the review are concerned with pickling of mild steel, electrolytic pickling, gas pickling, sodium-hydride pickling, and the acid pickling of stainless steels. In each case critical comment is made on the advantages and limitations of the processes to which reference is made.

Particular attention is directed to problems associated with the disposal of spent pickle liquor, a matter which has assumed increasing importance with the advent of laws relating to river pollution. A survey is made of current knowledge and experience with regard to the three most economic methods of disposal: (1) neutralization and subsequent disposal or use of the slurries, (2) extraction and use of ferrous sulphate, and (3) direct methods of recovery, whereby ferrous sulphate is converted into acid without separation. This section includes a note on electrolytic and gaseous hydrochloric-acid methods of regeneration.

The review closes with some discussion of other methods of de-scaling, including blast cleaning, mechanical de-scaling of wire rod, treatment by flame or induction heating, and scale removal by 'blasting off' after combined mechanical and heat-treatment. Reference is made also to the 'Efco-Virgo' process, which comprises swelling, cracking and conversion of the scale to an acid-soluble form by the action of a molten mixture of caustic soda

Compositions of Weld-Metals

Type	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Mo %	Cu %	V %
180	0·08	0·34	0·60	0·035	0·020	0·10	0·05	0·01	0·13	—
230	0·06	0·38	0·82	—	—	1·76	—	0·30	—	0·15
260	0·07	0·40	1·00	—	—	1·80	—	0·82	—	0·27

and an oxidizing agent, followed by water quenching, during which process the steam evolved dislodges most of the scale.

HEAT- AND CORROSION-RESISTING MATERIALS

Extrapolation of Stress-Rupture Properties in High-Temperature Alloys

W. BETTERIDGE: 'The Extrapolation of the Stress-Rupture Properties of the Nimonic Alloys.'
Jnl. Inst. Metals, 1957–58, vol. 86, Jan., pp. 232–7.

In view of the sparsity of long-term creep data, much attention has been devoted to methods of deducing long-period creep and rupture properties of high-temperature alloys from the results of short-time tests. The author of this paper makes a critical examination of four methods which have been proposed for this purpose. The accuracy of the respective procedures is evaluated on the basis of data obtained by their application to the high-nickel alloys Nimonic 80A (nickel-chromium-base) and Nimonic 90 (nickel-chromium-cobalt-base). The best results were obtained by using a time/temperature parameter of the form:

$$\frac{T - T_a}{\log t - \log t_a}$$

Where T is the temperature, t the time-to-rupture, and T_a and t_a are constants. Values of the constants are given for the two alloys mentioned, and for Nimonic 100, and the master curves of stress against the above parameter are plotted.

Age-Hardenable Nickel-Chromium-base Alloy: Specification

U.S. DEPARTMENT OF DEFENSE: 'Nickel-Chromium Alloy, Sheet and Strip, Age-Hardenable Annealed.'
Specification MIL-N-7786B, June 27, 1957; Superseding *MIL-N-7786A*, Mar. 14, 1955.

The specification covers annealed age-hardenable sheet and strip suitable for drawing and forming operations. The percentage compositional limits are as follows: carbon 0·08 max., silicon 0·50 max., manganese 1·00 max., sulphur 0·01 max., chromium 14.00–17·00, nickel (incl. cobalt) 70·00 min., niobium (incl. tantalum) 0·70–1·20, titanium 2·25–2·75, aluminium 0·40–1·00, copper 0·50 max., iron 5·00–9·00.

The specification lays down the mechanical properties of sheet and strip material in the annealed condition and it is required that after age-hardening at 1300° ± 10°F. (704° ± 6°C.) for 20 hours and air-cooling the material shall conform to the following requirements, in a direction perpendicular to the direction of rolling, when width permits.

Ultimate tensile strength ..	155,000 p.s.i. 69 t.s.i. 109 kg./mm.²
*Yield Strength at 0·2% offset or at 0·0105 in. (0·266 mm.) extension under load	100,000 p.s.i. min. 44·5 t.s.i. 70·5 kg./mm.²
*Elongation in 2 in. (50 mm.)	20% min.

* Applicable only to materials 0·010 in. (0·25 mm.) and over in thickness.

Precipitation-Hardenable Stainless-Steel Sheet and Strip

SOC. AUTOMOTIVE ENGINEERS: 'Steel Sheet and Strip Corrosion- and Moderate Heat-Resistant. 16·5Cr–4·5Ni–2·9Mo–0·1N (High-Temperature Annealed).'
S.A.E./A.M.S. Specification 5548; issued Jan. 15, 1958.

The material covered by this specification is intended for parts and assemblies in which high strength and oxidation-resistance must be maintained up to 800°F. (425°C.), which require maximum formability, and which may be subjected to welding during fabrication.

The percentage composition laid down is as follows: carbon 0·08–0·12, silicon 0·50 max., manganese 0·50–1·25, sulphur 0·030 max., phosphorus 0·040 max., chromium 16·00–17·00, nickel 4·00–5·00, molybdenum 2·50–3·25, nitrogen 0·07–0·13. Heat-treatment, and tensile and hardness properties after various heat-treatments, are specified for the material in three conditions: (i) annealed, quenched and rapidly cooled, (ii) re-annealed, precipitation-hardened and tempered, and (iii) re-annealed, sub-zero cooled and tempered.

Micro-Constituents in Steel: Extraction and Examination

See abstract on p. 107.

Machining of High-Temperature Alloys

A. B. ALBRECHT: 'Turning Operations on High-Temperature Alloys.'
Machinery (Lond.), 1957, vol. 91, Dec. 20, pp. 1431–4.

The article makes practical recommendations on the machining of various grades of high-temperature steels and alloys. The materials discussed are classified in three groups: (1) austenitic materials, which include a wide range of iron-base chromium-nickel-(molybdenum) alloys, (2) nickel-base age-hardenable alloys, (3) cobalt-base alloys.

Data on compositions, machinability ratings and recommended speeds and feeds are tabulated for materials representative of each of these classes. Information appropriate to the nickel-base alloys is reproduced in Table I, p. 110. (Reference is made also to a fourth classification, the ferritic straight-chromium corrosion-resisting steels, but this group is not discussed in detail, because the characteristics of such steels are already well known.)

The austenitic materials of the stainless-steel group are slightly abrasive and have shear strengths up

Table I

Composition, Machinability Ratings and Recommended Machining Speeds and Feeds for Age-Hardenable Alloys

(See abstract on p. 109)

Alloy	Composition							Machinability Rating†	Roughing Speed		Roughing Feed		Finishing Speed		Finishing Feed	
	C %	Ni %	Cr %	Co %	Ti %	Al %	Other Elements %		Surface ft./min.	Surface m./min.	in./rev.	mm./rev.	Surface ft./min.	Surface m./min.	in./rev.	mm./rev.
'Inconel' ..	0·04	76	15·8	—	—	—	—	30	80-125	24·5-38	0·010-0·017	0·254-0·431	100-150	30·5-45·5	0·004-0·010	0·101-0·254
'Incoloy 901' ..	0·04	45	13·0	—	2·50	—	Fe 33·0	20	75-90	23-27·5	0·010-0·017	0·254-0·431	85-100	26-30·5	0·004-0·010	0·101-0·254
'Nimonic 75' ..	0·10	77	20·5	—	0·35	0·15	—	17	65-80	20-24·5	0·010-0·017	0·254-0·431	75-90	23-27·5	0·004-0·010	0·101-0·254
'Inconel X' ..	0·04	73	15·0	—	2·55	0·80	—	15	50-65	15-20	0·010-0·017	0·254-0·431	55-70	16·5-21·5	0·004-0·010	0·101-0·254
'Nimonic 80' ..	0·04	75	21·0	—	2·50	0·60	—	12	40-60	12-18	0·010-0·017	0·254-0·431	45-60	13·5-18	0·004-0·008	0·101-0·203
'Hastelloy B'* ..	0·10	64	—	—	—	—	Mo 28·0	12	40-50	12-15	0·010-0·017	0·254-0·431	45-55	13·5-16·5	0·005-0·008	0·127-0·203
'Nimonic 90' ..	0·05	57	20·5	17·0	2·60	1·65	—	10	35-45	10·5-13·5	0·009-0·015	0·228-0·381	40-50	12-15	0·005-0·008	0·127-0·203
'Hastelloy C'* ..	0·15	55	16·0	—	—	1·00	Mo 17·0	10	35-45	10·5-13·5	0·009-0·015	0·228-0·381	40-55	12-16·5	0·005-0·008	0·127-0·203
'Udimet 500' ..	0·10	53	17·5	16·5	—	—	Mo 4·0	9	30-40	9-12	0·008-0·013	0·203-0·330	35-40	10·5-12	0·003-0·008	0·076-0·203
'Inconel 700' ..	0·10	46	15·0	29·0	2·00	3·00	Mo 3·0	8	30-35	9-10·5	0·008-0·013	0·203-0·330	30-35	9-10·5	0·003-0·008	0·076-0·203
'K-42-B' ..	0·05	42	18·0	22·0	2·00	0·60	—	8	—	—	—	—	20-30	6-9	0·003-0·008	0·076-0·203
'713'*	0·13	75	12·0	—	0·60	6·00	Mo 4·5	6	—	—	—	—	20-30	6-9	0·003-0·008	0·076-0·203

*Cast alloys. †Machinability ratings are based on the inherent strength and toughness of the respective materials. When determining cutting speeds the abrasiveness of the alloy must also be considered.

to 145,000 p.s.i. (64·5 t.s.i.; 102 kg./mm.²). Cutting speeds with the positive-rake carbide tools usually employed are normally kept below 200 surface ft./min. (61 m./min.).

The nickel-base age-hardenable alloys, due to their inherent strength and work-hardening characteristics, are somewhat difficult to handle. They are normally machined in the solution-treated condition, at speeds of 20–65 surface ft./min. (6–20 m./min.) and feed speeds are usually held below 0·015 in./rev. (0·38 mm./rev.): the depth of cut is held below 0·093 in. (2·3 mm.). Since these alloys are abrasive, and the feed loads required are exceptionally high, heavy-duty lathes are employed, and use is normally made of positive-rake tools. High rates of feed cause severe cold working, and are to be avoided.

The extreme abrasiveness of the cobalt-base alloys can be satisfactorily overcome only by the use of rigid (zero- or negative-rake) machining tools, low chip loads and slow speeds. These alloys work-harden severely ahead of the cutting edge and when secondary or finishing cuts are made they should be of sufficient depth to ensure that the cutting point of the tool is beneath the work-hardened surface left by the roughing operation.

In discussing general machining practice, the author refers to the severe abrasion to which tools are subjected and recommends the use of the harder carbide grades. In this connexion, it is considered vital that cutting speeds recommended as optimum for the respective materials should be maintained, and that the surface speed should be kept constant. In turning work which has a scaled surface, lower cutting speeds should be used, the work must be rigidly supported and the tool should not be permitted to dwell against the work. Feed rates of 0·0035 - 0·006 in./rev. (0·09 - 0·15 mm./rev.) and depths of cut ranging from 0·010 to 0·015 in. (0·25–0·38 mm.) are stated to produce a good surface finish. At feed rates below 0·0035 in./rev. (0·09 mm./rev.) there is a tendency to burnish the surface of the work.

The article ends with brief notes on coolants and horsepower requirements.

Nickel-containing Cast Irons in Turbo-charged Diesel Engines

See abstract on p. 106.

Welding of Waste-Gas Burner in 'Nimonic D.S.'

'The Construction of a Waste-Gas Burner in 'Nimonic D.S.''

Sheet Metal Industries, 1958, vol. 35, Feb., pp. 137–9.

The article gives details of procedure used to fabricate a waste-gas burner of relatively complicated design, the components of which were made almost entirely of the heat-resisting alloy 'Nimonic D.S.' (nominal composition: nickel 36–39, chromium 17–19, carbon 0·15 max., silicon 2·0–2·5, manganese 0·9–1·3, copper 0·25 max., per cent., remainder iron). For this material post-welding heat-treatment is usually unnecessary, since there is no risk of weld decay or peak hardening in the heat-affected zone, but the relatively high silicon content of the alloy necessitates precautions to minimize risk of cracking in the weld. For example, restraint on the joint during welding should be avoided, a small-gauge electrode should be used, and allowance must be made for interpass cooling. In fabricating the burner, it was found that entirely satisfactory results could be obtained by compliance with the following specification:

(1) Butt welding to be carried out with the material tacked at approximately $\frac{5}{64}$ in. (2 mm.) gap, which would close to $\frac{3}{64}$ in. (1·2 mm.) after tacking. Full fusion was to be obtained.

(2) Immediately prior to welding the parts were to be cleaned with a stainless-steel brush and subsequently cleansed with a solvent such as carbon tetrachloride.

(3) A 'back-stop' sequence of welding was to be adopted.

(4) Direct-current welding to be used, with a current value in the lower part of the range recommended by the makers of the alloy.

(5) Electrodes to be stored at constant temperature in a dry oven, to reduce the moisture content to a minimum.

(6) Open-corner welds to be of rounded contour and the wall thickness of the basis metal not to be reduced.

The design of the burner is described, with detailed illustrations, and particulars are given of fabrication methods.

Electrolytic Polishing of Stainless Steel

P. F. McKINNEY: 'Electrolytic Polishing of Stainless Steel.'

Chemical and Process Engineering, 1958, vol. 39, Feb., pp. 59–60.

The article gives brief details of the 'Electropol' process, by means of which, it is claimed, stainless-steel equipment of any shape or size can be satisfactorily polished.

The hygienic and corrosion-resisting qualities of polished surfaces are emphasized and some examples are given of applications in which these properties are utilized to advantage, e.g., in chemical, food, hospital and atomic energy equipment.

Pickling of Steels

See abstract on p. 108.

Sintered Corrosion-Resisting Steels

F. EISENKOLB: 'Production and Properties of Sintered Corrosion-Resisting Steels.'

Stahl und Eisen, 1958, vol. 78, Feb. 6, pp. 141–8.

Commercial exploitation of powder-metallurgy production of steels is limited by both economic and technical difficulties. Some of the latter problems

have been particularly acute in relation to production of stainless steels, due, in large measure, to the inherent characteristics of the metals essential in such materials. Powder-metallurgy manufacture of stainless-steel components is thus still in a relatively experimental stage. In view of the known advantages of the technique it is, however, desirable to develop it as a means of forming certain types of component, and much study is now being devoted to improvement of pressing and sintering techniques, in order to achieve, in powder-metallurgy parts, density and mechanical properties equal to those typical of wrought and cast materials of comparable compositions.

In this paper the author gives details of investigations of the effects of sintering and other conditions which influence the properties of corrosion-resisting steels and related materials in final-product form.

The paper opens with a discussion (including due reference to the literature) of the principal methods used for production of the powder raw materials: (*a*) in the form of pre-alloyed powders, or (*b*) as elemental powders for synthetic manufacture of steels. Reference is made to production of stainless-steel powder by intercrystalline disintegration of unstabilized nickel-chromium steel, by mechanical pulverizing, by atomization of molten materials by water or air blast under high pressure, and by the hydride process. The nature of the particles produced and the effect of their respective shapes on sintering quality are reviewed, with comment on the more favourable sintering characteristics of the spiky particles resulting from high-pressure, high-temperature disintegration, as compared with the globular form of powders made under lower-temperature, lower-pressure conditions. (It is pointed out, however, that for filters or other purposes in which the end product is to be a uniform porous mass, the latter type of powder has advantages.) It is noted also that in production of stainless-steel powder the use of air as a disintegrating medium is to be avoided, in view of the heavy oxide skin thus formed on the particles, which causes trouble in subsequent sintering. Better results are obtained by using water or nitrogen as the blast medium. A tabular comparison is made of the shapes of powders produced by various methods, their flow qualities, and the mechanical properties typical of sintered compacts prepared from the respective powders.

It is pointed out that, up to the present, attainment of practically useful properties in powder-produced components has been possible only by means of a double-press-and-sinter technique, using high pressures and elevated temperatures. The author's experiments were therefore designed to determine conditions which would ensure production of strong, ductile steels by means of a single pressing and sintering operation, using temperatures of about 1200°C.

Consideration was first given to the influence of furnace atmosphere during sintering. Following earlier investigations, hydrogen was used, and the results showed that it is important to have a gas of the highest possible purity, in order to reduce, as completely as possible, the oxide film which inhibits satisfactory sintering of the powders. Further tests, in which other gases were added with a view to enhancing the reducing action, were not sufficiently successful to warrant expectation of use under industrial conditions, and results of sintering in vacuo were not promising.

The second series of experiments dealt with sintering under conditions favouring formation of a liquid phase between the powder particles. Following earlier experiments, the author used red phosphorus, and he also reports test data obtained on boron-containing masses. (For fuller details of results with boron, see following abstract.) The sintered bodies obtained in this series gave mechanical properties (after single pressing and sintering) higher than any previously obtained other than by the double-pressing and sintering technique.

Tests on production of straight-chromium steel from powder made by the Hametag (mill-pulverization) process showed that in steels of suitably low carbon content it was possible to attain mechanical properties equal to those of chromium steel of similar composition made by conventional methods.

A further series of tests was made on material produced by sintering some of the chromium-steel powder with carbonyl-nickel powder. After pressing under 6 tons per sq. cm. and sintering for 2 hours at 1200°C in purified hydrogen, tensile strengths of the order of 50 kg./mm.^{2} (31·5 t.s.i.) were obtained in the chromium-nickel steels. Addition of red phosphorus increased the strength to about 60 kg./mm.^{2} (38 t.s.i.). The higher-strength steels showed, however, somewhat low elongation (less than 10 per cent.).

Diffusion experiments, in which steels were 'chromized', emphasized the need for ensuring a non-porous starting material, since there was a tendency towards retention of ferrous chloride in the pores of the sintered compact. Plugging of the pores with water glass, before chromizing, or addition of phosphorus to the iron powder, followed by simultaneous chromizing and sintering, are suggested as remedial measures.

High-nickel steels, although not included in the general category of corrosion-resisting steels, were also examined by the author, using 25 per cent. nickel steel. The results showed that if powder produced by pulverization of mass steel of the required composition is used, oxidation + reduction treatment is necessary before sintering. Tests on nickel steel of the same nickel content, but produced by sintering a mixture of elemental powders at 1200°C. for 4 hours, showed a similar level of properties, viz., tensile strength of about 40 kg./mm.^{2} (29 t.s.i.) with a porosity of about 8 per cent. Elongation was low; of the order of 4 per cent.

Brief reference is made to corrosion tests of sintered corrosion-resisting steels, in *N*/2 hydrochloric acid, and to erosion (water-hammer) tests, the apparatus for which is illustrated. Resistance to both forms of attack is mainly a feature of the porosity of the sintered material, emphasizing the need for high density in the powder-made product.

Effect of Boron on Properties of Sintered Nickel-Chromium Stainless Steels

F. BENESOVSKY and W. HOTOP: 'Influence of Boron on the Formation of Liquid Phases in Sintered Steel, with Special Reference to Steels containing Chromium 18, Nickel 8, per cent.'

Stahl und Eisen, 1958, vol. 78, Feb. 6, pp. 149–52.

Experimental work designed to improve the properties of metallic materials produced by powder metallurgy has been directed not only to study of the influence of pressing and sintering conditions, but also to selection of the most favourable types of starting material, and the optimum form and physical condition in which to use them. Some success has been achieved by the introduction, into the powder mass, of materials which are conducive to formation of a liquid phase during sintering (e.g., by formation of a low-melting eutectic). In the case of iron-base alloys ferroboron additions have proved effective, particularly in production of 18-8-type chromium-nickel steels, which, on account of the oxide films present on the surface of the powder particles, are difficult to sinter. Additions of less than 2 per cent. of ferroboron have been found to increase the density of such steels to a considerable extent, with corresponding improvement in tensile strength and hardness. The disadvantage of such additions is, however, that they deleteriously affect ductility and impact-resistance, and with ferroboron contents of about 6 per cent. the steels became extremely brittle. Further investigations were therefore carried out by the present authors with a view to developing an addition medium which would improve density, strength and ductility, by formation of a liquid phase, and simultaneously act as a beneficial alloying agent. These considerations formed the background to the work reported in this paper, which covered the effect of additions of a nickel-chromium-boron alloy on the density, structure and mechanical properties of steels made by sintering (1) various iron powders, and (2) stainless-steel powders.

The composition of the addition alloy (melting point approximately 1100°C.) was carbon 0·3, silicon 3·4, nickel 72, chromium 18, boron 4·2, iron 2·1, per cent. The basis materials to which such additions were made consisted of four grades of iron powder (carbonyl, Hametag, sponge-iron and Mannesmann), and powders obtained by intercrystalline disintegration of 18-8-type chromium-nickel steel. Additions of 2, 4, 6, 8 and 10 per cent. of the nickel-base alloy were made to each grade of iron powder, and the compacts were sintered at 1100°C. for one hour. In the case of the stainless-steel powder, the alloy additions were 2, 4 and 6 per cent. and sintering was for two hours at 1250°C.

Data are presented on the density, hardness, tensile strength and impact-resistance of the steels at each level of alloy content, and photomicrographs illustrate the structures obtained. In steels made from iron powders, increasing alloy content significantly improved density, hardness and tensile strength: ductility and impact-resistance were lowered. The results obtained with the various grades of iron-powder base varied somewhat according to the particle size of the starting materials. The addition of increasing percentages of nickel-base alloy to the stainless-steel powder also resulted in increase in density, hardness and tensile strength: initially (up to 2 per cent. nickel-chromium-boron content) ductility also rose considerably, but with higher alloy additions there was some fall. The deterioration in ductility and impact-resistance was not, however, serious, even at a 6 per cent. addition.

Metallographic examination of sintered alloyed specimens showed that the grains of stainless steel were surrounded by a relatively tough nickel-chromium-boron eutectoid, and that grain growth increased with increase in the amount of liquid phase present. Structurally, the results are explained in terms of the presence, with alloying additions up to 2 per cent., of a relatively uninterrupted, soft, tough, stainless-steel matrix which is favourable to tensile strength and ductility. If, however, the grains of stainless steel are surrounded by the hard, tough, additive material (present in compacts containing higher amounts of the nickel-base alloy) hardness and tensile strength increase, at the expense of ductility.

Specimens of these steels heated in air in the range 700°–900°C. were found to give good oxidation-resistance, and they are stated to be also satisfactorily resistant to abrasion and corrosion.

Sintered Filters of Nickel-containing Materials

J. KOVACS: 'Porous Metal Filter Media Solve Tough Operating Problems.'

Materials in Design Engineering, 1958, vol. 47, Jan., pp. 126–8.

Metallic filter components, made by sintering metal powder of controlled particle size to obtain the desired porosity and pore dimensions, have been developed for service under pressure and temperature conditions too severe to permit the use of more conventional filter media such as cellulose, plastics and glass. In most cases the metallic filters are selected also with particular reference to their corrosion-resisting qualities.

Among the materials successfully used in filter consistencies are various grades of simple and complex stainless steels, 'Monel', 'Inconel', 'Hastelloy', bronze, nickel silver, gold, and silver. Pore sizes frequently range between 4 and 25 microns, but can be as small as 0·2 micron. Density varies from 40 to 50 per cent. of the theoretical density of the bulk material.

Filters of this type, originally developed primarily for use in aircraft hydraulic systems, are now employed successfully in many types of chemical plant, petroleum equipment, and atomic energy plant, as well as in other industries. This article gives numerous examples of the applications of the porous media in filtration and gas diffusion. The advantages of thin-wall materials over thick-wall sections are also discussed.

Production, Processing and Uses of Metal Powders

See abstract on p. 96.

Nickel-containing Materials in an Oil Refinery

'Over a Million Pounds of Nickel in Alloy Form used in Refinery of the Future.'

INCO, 1957, vol. 27, Dec., pp. 1–7.

The Tidewater Oil Company's refinery near Delaware City, with its capacity of 130,000 barrels per day, is one of the largest and most modern yet built: five of the eleven processing units are the world's largest. Advantage has been taken of experience in other refineries, not only to improve the design of the plant, but also in the matter of minimizing corrosion by selection of appropriate materials of construction. This latter factor received particular consideration because the plant has been designed to refine corrosive crudes from all over the world, and brackish water from the Delaware River is used for the cooling system.

The article details the use of alloys and steels containing over a million pounds of nickel (over 446 tons; 453,590 kg.), employed in the refinery in materials chosen for their ability to resist corrosion by such media as sulphur, naphthenic acid, chlorides and other compounds in the cooling water, hydrogen-sulphide/hydrogen mixtures, diethanolamine solutions, carbon dioxide, and hydrogen.

Particulars are given of materials of construction used for the main components of the plant, including those in the crude-distillation unit, the fluid coking system, the hydro-desulphurization unit, the gas-recovery plant and the hydrogen plant. Various grades of 18–8 type chromium-nickel stainless steels, 'Monel', 'Incoloy' and 'Inconel' have been widely employed.

Stainless Steels in the Petroleum Industry

F. A. KIRK and J. WILLIAMS: 'Stainless Steels for the Petroleum Industry: A Comparison of British and American Qualities.'

Brit. Petroleum Equipment News, 1957–58, vol. 6, No. 3, pp. 40–6.

Abridgement of paper presented at study days organized by Federation of European Petroleum Equipment Manufacturers, at Stuttgart, October 1957.

During the past few years advances in chemical technology have resulted in increasingly exacting requirements for metallic materials used in chemical plant, and no group has called for a wider variety, or made more severe demands, than the petroleum and its related industries. Materials are required to resist atmospheric corrosion under industrial and marine conditions, wet and dry chemical corrosion, high-pressure steam at elevated temperatures, corrosion and scaling conditions involving hydrogen sulphide and sulphur dioxide, in reducing and oxidizing atmospheres. Associated with these requirements is the need for strength at high temperatures and structural stability, in order to obviate any form of embrittlement.

Close co-operation between the petroleum refineries, the steelmakers and the fabricators of plant has led to the establishment of certain steels as being essential to the safe, efficient and economic running of refinery plant, and in the U.K. and the U.S.A. a comprehensive series of specifications has been set up to meet the needs of the industry. (In the full form of the paper, as presented at the Conference, a tabular comparison was made of the relevant B.S. and A.S.T.M. schedules.)

The authors make a detailed survey of the compositions, properties and uses of the following types of steel, with recommendations on fabrication and heat-treatment: the characteristics of the respective types, are discussed in relation to their use in the petroleum industry.

Wrought Steels	5, 13, 17 and 20% chromium 18–8% chromium-nickel
Cast Steels	18–10% chromium-nickel containing molybdenum 25–12 and 25–20% chromium-nickel 5, 9, 13, 17 and 27% chromium.

Mention is made also of certain special types of steel not covered by British specification; among these are the high-manganese/low-nickel austenitic steels; precipitation-hardening types, such as 'Stainless W', 'Armco 17–4 P.H.' and '17–7 P.H.', 'A.M. 350', '17–10 P' and 'H.N.M.', also austenitic stainless steels in which copper and molybdenum are added to enhance resistance to certain corrosive media.

In conclusion, the authors emphasize the importance of providing, to the steelmaker, full details of the conditions in which equipment will be used, and of indicating, where possible, the standard specification to which materials should be supplied.

Clad Steels in the Petroleum Industry

J. ERSKINE: 'The Manufacture and Use of Clad Steels.'

Brit. Petroleum Equipment News, 1957, vol. 6, No. 2, pp. 40–5.

After brief consideration of the technical and economic advantages of cladding, the author reviews the methods by which clad materials are produced. Particular attention is given to the method involving hot rolling of a double-sandwich-type pack, comprising outer sheets of mild steel, with separable centre sheets of the cladding material. Separation, after rolling, gives two clad sheets from each double pack. The technique of production by this method is illustrated, and reference is made to precautions taken to obviate non-adhesion which might arise from the chromium-oxide film present on stainless steels used as cladding. By this process many thousands of tons of clad material are annually produced, for various types of chemical equipment.

Clad steels were 'born' in America, and in that country specifications have been established to cover cladding with most of the important corrosion-resisting materials. This paper contains a list of the U.S. Specifications, with notes of equivalent material supplied in the U.K. by Messrs. Colvilles, Limited, under the designation 'Colclad'. Reference

is made to the British Standard Specification covering nickel-clad material, and comparisons are made between American and British Standard Specifications for the types of steel employed for the backing-plate component.

The second section of the paper contains short notes on the mechanical properties of clad steels (including a table showing typical values), and on the processing of the composite materials by gas cutting, cold-working, hot-forming, shearing, and punching. Attention is directed to precautions necessary in welding of clad steels, with particular reference to avoidance of iron dilution of the cladding metal. (In this connexion see also recommendations on welding of clad steels made in paper by J. HINDE, published in *Welding and Metal Fabrication*, 1956, vol. 24, pp. 11–15, 59–62.)

Although the varied types of corrosion and temperature conditions obtaining in refineries preclude full consideration, in one paper, of the many uses of clad steels, the author gives four illustrations indicating some typical applications in plant operated by Shell Petroleum Company at Cardon and by British Petroleum Company in their Grangemouth refinery.

Use of Stainless Steels in Paper Mills

E. DIEDRICHS and B. HEDSTRÖM: 'Black-Liquor Evaporation. I. Some Problems of Construction and Operation.'

Svensk. Papperstidn., 1956, vol. 59, pp. 561–9.

Design factors involved in the optimal utilization of the heat-exchange surface in a paper-mill evaporation plant are considered in the light of conventional installations. *Inter alia*, the relative suitability, for evaporator tubes, of two stainless steels is discussed: (*a*) nickel 5, chromium 13, per cent., and (*b*) chromium 18, nickel 8, per cent.

Nickel Equipment used in Deodorization of Vegetable Oil

See abstract on p. 100.

Stainless-Steel Tanks for Shipping Wine and Other Liquids

'A New Concept in Tankers for Carrying Liquid Cargoes.'

INCO, 1957, vol. 24, Dec., pp. 14–15.

The article describes the unusual features of the 'Angelo Petri', a special food-products tanker owned by United Vintners Inc., San Francisco.

This vessel, which was designed primarily to transport the company's products, has a capacity of 2,500,000 gallons (11,364,900 litres) of wine in its 26 cargo tanks. The ship plies between Stockton, California, and Port Newark, N.J. At the latter port, the major portion of the wine cargo is unloaded, together with the 1,200,000 gallons (5,454,152 litres) of lubricating oil which, for economic reasons, are also carried by the tanker (in 14 ballast tanks completely isolated from the main cargo tanks). After discharge, the ship re-loads with liquid cargoes such as alcohol, edible oils and lubricating oils, and the return journey to Stockton is made with an intermediate stop at Houston, Texas, to discharge the remaining wine cargo and pick up corn sugar, molasses, etc.

The 'Angelo Petri' is distinguished from an ordinary tanker by the fact that its 26 cargo tanks, having capacities ranging from 31,000 to 211,000 gallons (117,335 to 798,635 litres) are clad with 1,800,000 lbs. (817 metric tons) of chromium-nickel-molybdenum stainless steel of the 18-8 type. The excellent resistance of this steel to corrosion by the mild acids present in food products ensures sterility of the cargoes carried, and the preservation of hygienic conditions is still further facilitated by design features which permit easy and thorough cleaning of the tanks. In addition to the cargoes mentioned, the ship also carries over 200,000 gallons (757,000 litres) of fresh water for cleaning the tanks en route after unloading.

Welded Stainless-Steel Tubing

SOC. AUTOMOTIVE ENGINEERS: 'Steel Tubing, Welded, Corrosion- and Heat-Resistant. 18Cr–11Ni–(Nb+Ta) (S.A.E. 30347).'

S.A.E./A.M.S. Specification 5558; issued Jan. 15, 1958.

The material covered is primarily for use for high-pressure air ducting in which corrosion- and heat-resistance is required, especially for applications in which the ducting is welded during fabrication and in which the wall thickness is approximately 2 per cent. or less of the outside diameter.

Percentage composition is as follows: carbon 0·08 max., silicon 0·50–1·00, manganese 2·00 max., sulphur 0·030 max., phosphorus 0·040 max., chromium 17·00–19·00, nickel 9·00–12·00, niobium +tantalum 10×C–1·10, molybdenum 0·50 max., copper 0·50 max. Tensile requirements are laid down, also bend tests, method for determining susceptibility to weld cracking, pressure test, and embrittlement test.

SOC. AUTOMOTIVE ENGINEERS: 'Steel Tubing, Welded, Corrosion- and Heat-Resistant. 18Cr–10Ni–Ti (S.A.E. 30321).'

S.A.E./A.M.S. Specification 5559; issued Jan. 15, 1958.

This specification covers another type of steel for thin-walled tubing. Percentage composition is as follows: carbon 0·08 max., silicon 0·40–1·00, manganese 2·00 max., sulphur 0·030 max., phosphorus 0·040 max., chromium 17·00–19·00, nickel 8·00–11·00, titanium 6×C–0·70, molybdenum 0·50 max., copper 0·50 max. The tests laid down are similar in character to those incorporated in *A.M.S.* 5558.

Nickel-Alloy Welding Electrodes

SOC. AUTOMOTIVE ENGINEERS : 'Alloy Welding Electrodes, Coated, Corrosion- and Heat-Resistant. Nickel-base-15Cr-(Nb+Ta)-1·9Ti-0·6Al.'

S.A.E./A.M.S. Specification 5779; issued Jan. 15, 1958.

The electrodes specified are required to be capable of depositing weld metal of the following percentage composition: carbon 0·25 max., silicon 1·0 max., manganese 1·0 max., sulphur 0·015 max., chromium 12·5–17·0, nickel+cobalt 66·0 min., cobalt (if determined) 1·0 max., niobium+tantalum 4×Si min., titanium 1·0–2·75, aluminium 0·10–1·0, iron 11·0 max., copper 0·50 max. Such electrodes are intended primarily for welding alloys of composition similar to that of the deposited weld metal.

PATENTS

Stabilized Raney-Nickel Catalyst

The pyrophoric nature of dried Raney nickel has hitherto made it impracticable to market a ready-made form of the catalyst. The invention covered by this patent consists in production of a stable Raney nickel by forming a solidified suspension of the material in a fatty alcohol having 16–26 carbon atoms per molecule inclusive. Such a solid suspension is stable in air at room temperature, and it is claimed that even after six months' storage the catalytic activity of the nickel can be made fully available by dissolving out the fatty alcohol by means of ethyl or methyl alcohol or other suitable solvent. The fatty alcohol used for the suspension is preferably cetyl, stearyl or ceryl alcohol.

BRITISH DRUG HOUSES, LTD.
(inventors, C. OCKRENT, G. E. H. SKRIMSHIRE and A. J. SUTHERLAND). *Brit. Pat* 791,658
(Similar to *Belgian Pat.* 547,306)
(„ „ *French Pat.* 1,147,867).

Nickel-containing Dehydrogenation Catalysts

Catalysts for dehydrogenation of a mono-olefin consist of a double phosphate of calcium and nickel, in granular form, mixed with a lubricant. Chromium oxide may also be present.

POLYMER CORPN., LTD.
(inventors, W. J. L. KEARNS, P. M. REILLY, E. P. LEWIS, D. S. ALEXANDER and C. AMBRIDGE).
Belgian Pats. 556,909; 557,369.

Activation of Nickel Electrodes

A porous nickel electrode for an alkaline battery is activated by inclusion of a mixture of indium (preferably 0·5–2 per cent.)+cadmium.

A. FLEISCHER, assignor to NICKEL-CADMIUM BATTERY CORPN. *Canad. Pat.* 548,802.

Supports for Oxide-Coated Cathodes

Longer life is obtained in oxide-coated cathodes by making the support for the emissive layer of a mixture consisting essentially of a nickel powder and 0·1–10 per cent. of its weight of a refractory carbide. Tungsten carbide is the preferred refractory substance.

A tablet of this mixture is sintered at 1250°C. for two hours and the cathode support is shaped by usual methods. A cathode is then made up by coating the support with a mixture of calcium, strontium and barium carbonates, e.g., in molecular proportions of 5, 45 and 50 per cent., respectively. It is stated that cathodes so made retain about 25 per cent. of their emissive power after having operated for 10,000 hours.

CIE. GÉNÉRALE DE TÉLÉGRAPHIE SANS FILS.
Brit. Pat. 789,826.

Nickel Alloys Showing High Secondary Emission

Nickel-base alloys for use as secondary emitters contain critically proportioned amounts of elements of group IIA of the Periodic Table, preferably beryllium or magnesium. The preferred amounts of the addition elements are 2·5–4·5 per cent. of beryllium, or 0·6–2 per cent. of magnesium. The function of the added metal is discussed in relation to alloys containing varying amounts of beryllium, and details are given of heat-treatment.

STÉ. LE CARBONE-LORRAINE, S. TESZNER and J. MILLET.
Brit. Pat. 787,178
(Similar to *French Pat.* 1,085,073
and *Patent of Addition* 65,987).

Age-Hardenable Nickel Alloys for Grid Wires

Grid wires used in electrical discharge devices are made from an alloy which in the solution-treated, cold-drawn and annealed condition can be easily fabricated and is subsequently strengthened by ageing at a temperature above the maximum to which the grid will be subjected during service. The recommended ageing temperature is 650°C. The compositions of preferred alloys are:

(1) Aluminium 4–6, chromium 2·5–20, wt. per cent., balance nickel.

(2) Aluminium 2·5–5, titanium 4–7·5, wt. per cent., balance nickel.

Tensile strengths ranging from 90 to 100 kg./mm.^{2} (57–63·5 t.s.i.) and elongation of 19 per cent. have been obtained in the aged condition. It is claimed that wires produced in this way exhibit substantially no distortion during the life of the valve.

M-O VALVE CO., LTD.
(inventor, H. C. COE). *Brit. Pat.* 790,545.

Deterioration of wires operating at high temperatures, e.g., grid wires in electric discharge devices, is prevented by using an age-hardenable alloy of the following composition: aluminium 2·5–8, chromium and/or titanium 2·5–20, per cent., balance nickel or nickel+cobalt. (The amount of cobalt which may be present, in replacement of nickel, is limited to 20 per cent.) The nickel used is preferably made by the carbonyl process. The preferred series of

fabrication operations is as follows: hot-rolling the ingot to rod, solution-heating the rod and quenching, cold drawing to wire, strand annealing the wire, and finally age-hardening it by heating in a non-oxidizing atmosphere at a temperature above 300°C. (The exact temperature of the ageing treatment is determined by the composition of the alloy within the range specified.) The properties of some typical alloys show the influence of composition and treatment. Preferred compositions are cited as
(1) aluminium 5, chromium 5, nickel 90, per cent.;
(2) aluminium 3·5, titanium 4·5, nickel 92, per cent.

GENERAL ELECTRIC CO., LTD. *Brit. Pat.* 790,303.

Bright-Nickel-Plating Solutions

The brightening agent in a nickel-plating solution consists of an organic sulphonic acid of formula G-R-SO_3H, where G is a halogen atom or a CN or SCN group, and R a saturated aliphatic hydrocarbon radical. Example: (g./L.) $NiSO_4$ 200, $NiCl_2$ 60, H_3BO_3 40, 4-iodo-butane Na sulphonate 7.

DEHYDAG DEUTSCHE HYDRIERWERKE, G.m.b.H.
Brit. Pat. 787,186.

Bright Ductile Electrodeposited Nickel Coatings

Very bright and ductile nickel coatings are produced (on a basis metal of surface smoothness corresponding to a R.M.S. value not exceeding 50) by electrodeposition (1) of a 0·5-1·5 mil layer of semibright* nickel, followed immediately by electrodeposition of 0·1-0·5 mil of bright* nickel. Such composite coatings are stated to be level, adherent and corrosion-resistant, and to form an excellent basis for the deposition of fully bright chromium deposits. Compositions typical of both semibright and bright solutions are given in the patent.

* NOTE.—In this patent the term 'Watts-coumarin-semibright' solutions indicates electrolytes of the type claimed in *Brit. Pat.* 622,761, according to which a nickel-plating solution contains a small proportion of coumarin or of its alkyl or acyl derivatives, or of the halogen, hydroxy or carboxy derivatives of the coumarin. Reference is also made to solutions containing, in addition to the above constituents, one or more auxiliary brighteners selected from aromatic sulphonic acids, sulphonates, sulphonamides and sulphonimides and their salts, and sulphonyl chlorides (with or without other brighteners). Such solutions are designated 'Watts-coumarin-bright' solutions.

HARSHAW CHEMICAL CO. *Brit. Pat.* 789,887.
(Similar to *Australian Pat.* 200,741)

Preparation of Molybdenum, Zirconium and Other Metals for Electroplating

Uranium, zirconium, titanium, tantalum, niobium, molybdenum, tungsten or vanadium is plated with nickel or other metallic coatings after being shot-blasted and flash-coated with an undercoat of copper deposited, by chemical displacement, from a specified electrolyte. It is claimed that the adhesion so obtained in the coatings is much superior to that of coatings deposited on a basis prepared by electrochemical cleaning only.

U.K. ATOMIC ENERGY AUTHORITY
(inventors, R. A. U. HUDDLE and O. FLINT).
Brit. Pat. 788,721.

Electrodeposited Coatings for Protection of Molybdenum and Tungsten

Molybdenum, tungsten or their alloys are protected from oxidation at elevated temperatures by adherent coatings of nickel, nickel alloys, cobalt, iron or their alloys. Coatings having specific properties are produced by depositing on the molybdenum or tungsten or their alloys a coating of copper and zinc (or a copper-zinc alloy), annealing the coated article in a non-oxidizing atmosphere at 900°-1000°C. until the zinc has been completely volatilized, and then electrodepositing a coating of nickel-iron or cobalt or their alloys over the de-zincified residual copper. The invention is illustrated by a description of the procedure used to coat molybdenum with nickel and a nickel-manganese alloy. Details are given also of electrolytes suitable for depositing cobalt and iron.

GENERAL ELECTRIC CO. *Brit. Pat.* 783,807.

Forming of Nickel Tubes by Electroless Deposition

Hollow nickel parts, in particular tubes of small diameter, are produced by depositing nickel by chemical reduction (electroless plating) onto a core wire of a material which can be subsequently dissolved away by a reagent which does not attack the nickel. The preferred core material is aluminium, which is dissolved out by immersion, for 3-5 hours, in a solution of 50 per cent. NaOH, used at 105°C.

STÉ. EUROPÉENNE DE REVÊTEMENT CHIMIQUE (SEUREC).
French Pat. 1,152,582.

Metallizing of Ceramics by Deposition of Nickel/Copper Coatings

Ceramic components (e.g., capacitors) are metallized, (to make them electrically conductive and also suitable for soldering,) by deposition of three metallic layers: an initial flash coating of nickel, (deposited by thermal decomposition of nickel carbonyl), which provides adherence to the ceramic; an intermediate flash coating of electrodeposited nickel, and a final coating of electrodeposited copper.

ERIE RESISTOR CORPN. *Brit. Pat.* 788,763.

Nickel-Alloy Leads for High-Wattage Lamps

High-wattage lamps, as used, for example, in television and motion-picture studios, tend to give an audible hum. This patent describes a design of lamp comprising a sealed bulb and having lead-in conductors of a ferromagnetic copper-containing alloy which is free from magnetostriction and thus prevents audible hum. Examples include use of 'Monel' or other types of nickel-copper alloy.

GENERAL ELECTRIC CO. OF U.S.A. *Brit. Pat.* 786,994.

Nickel in Copper-base Brazing Alloys

An alloy claimed to be specially suitable for brazing mild, low-alloy or stainless steel, e.g., in heat-exchanger parts which will be subjected to elevated temperatures and relatively high pressures, is of the following composition: copper 85–95, nickel 3·5–10·5, chromium 0·825–2·44, boron 0·175–0·56, per cent. It is specified that the iron + silicon + carbon content shall be not more than 1·5 per cent. The alloy is characterized by good strength and by resistance to creep and to corrosion, at temperatures of 90°–1200°F. (32°–650°C.).

AIR PREHEATER CORPN. *Brit. Pat.* 789,653.
(Similar to *Belgian* ,, 548,661)

Nickel in Titanium-base Alloys

A titanium-base alloy contains aluminium 0·5–12, copper 5–20, cobalt 5–12, nickel 5–12, per cent., titanium balance.

REM-CRU TITANIUM, INC. *Australian Pat.* 210,366.

Wrought High-Temperature Alloys

An alloy is claimed as having stress-rupture properties and fatigue strength at 1600°F. (870°C.) superior to those of other known alloys, combined with good resistance to corrosion. The composition limits are: nickel 25–35, cobalt 35–40, chromium 20–25, titanium 4–7, carbon 0·5–1·5, per cent., with 1–3·5 per cent. of one or more of the elements tungsten, molybdenum, niobium + tantalum, iron balance. The alloy is solution-treated at 2150°F. (1175°C.), and aged at 1650°F. (900°C.). Particular emphasis is placed on the strengthening influence of the titanium constituent. Vacuum melting is preferred, as preserving in the alloy the maximum amount of effective titanium, and ageing is adjusted to secure precipitation of the Ni_3Ti intermetallic compound in a finely dispersed state.

Hardness, stress-rupture, mechanical properties and fatigue data are quoted for alloys of varying compositions within the specified range, and the influence of thermal treatment on properties is demonstrated.

GENERAL ELECTRIC CO. OF U.S.A. *Brit. Pat.* 788,125.

Alloys for use at temperatures of about 1650°F. (900°C.), claimed to have higher strength and stability at such temperatures than alloys currently available, contain (at. per cent.) carbon 0·1–2, cobalt 30–45, nickel 20–35, chromium 15–30, tungsten 1–7, molybdenum 0–5, tantalum 0–5, niobium 15–30, tungsten 1–7, molybdenum 0–5, tantalum 0–5, niobium 0–3, titanium 3–9, boron 0·005–0·6, iron 0–5.

The patent also claims a heat-treatment involving solution treatment at 2150°F. (1175°C.), followed by ageing in the range 1650°–1700°F. (900°–925°C.). Data are presented on the mechanical properties of typical alloys, at various temperatures, as influenced by composition and by the temperature of the ageing treatment. The alloys are stated to be particularly suitable for turbine blading.

GENERAL ELECTRIC CO. OF U.S.A. *Brit. Pat.* 788,956.

Heat- and Corrosion-Resisting Alloy

An alloy claimed to show outstanding resistance to heat and high-temperature corrosion contains carbon 0·1 max., nickel 30–35, chromium 12–15, tungsten 5·5–7·5, molybdenum 2·5–5, titanium 1·5–3, aluminium 0·5 max., zirconium 0·5 max., per cent., balance iron.

GENERAL ELECTRIC CO. OF U.S.A.
(inventors, R. W. GUARD and P. J. CLEMM).
Belgian Pat. 557,872.

High-Temperature Alloys Produced by Powder Metallurgy

The compositions of two groups of alloys claimed to be suitable for use in turbine blading and other high-temperature parts are shown below. In both cases production is by powder-metallurgy methods. (1) Nickel 9–11, titanium 31–33, carbon 16–18, chromium 14–16, tungsten 3–5, cobalt 21–23, per cent. (2) Nickel 39–41, titanium 34–36, carbon 14–16, chromium 9–11, per cent.

Both types of alloy are claimed to have specially high resistance to corrosion by salts.

R. L. PETTIBONE, assignor to EATON MANUFACTURING CO. *U.S. Pats.* 2,818,331; 2,818 332.

Production of Nickel-containing Cermets

Cermets are produced by casting, in a plaster of Paris mould, a slip prepared from a mixture of refractory oxides and metals and/or metalloids, and firing the mixture at a temperature above 1000°C. Subsequent drying at 50°–200°C. is also claimed. Of the refractory oxides suitable for use in this process, particular reference is made to alumina, chromia and magnesia: the metals which may be used include chromium, nickel, iron, titanium, austenitic steels, niobium and molybdenum. A cermet consisting of nickel and magnesia is specifically mentioned.

IMPERIAL CHEMICAL INDUSTRIES, LTD.
(inventors, F. R. HIMSWORTH, A. W. ELMES and L. G. HUGGETT). *Brit. Pat.* 790, 621.

Electrical-Resistance Alloy

An electrical-resistance alloy contains chromium 8–28, manganese 15–36, molybdenum 0·1–4, aluminium 0·1–3, cobalt 0·5–5, per cent., balance nickel. It is claimed that in the annealed state this alloy has a resistivity of Ω 800 /circular mil ft.

J. H. JACKSON and J. F. KAVANAUGH, assignors to C. O. JELLIFF MANUFACTURING CORPN.
U.S. Pat. 2,817,586.

Thermocouples Resistant to Attack by Furnace Atmospheres

Thermocouples for use at high temperatures, capable of developing high thermal e.m.f. and resistant to surface deterioration which would affect calibration, consist of an electropositive element made from a nickel-chromium-base alloy and an electronegative element made from a nickel-base alloy containing small amounts of silicon, iron and man-

ganese. Composition ranges for the two legs are given as follows:

Electropositive element: chromium 8–10, iron, manganese, silicon and niobium 0–2 per cent. each, balance essentially nickel.

Electronegative element: silicon 2–7, iron and manganese 0–2 per cent. each, balance essentially nickel.

Typical compositions are given of such thermocouples and their behaviour at temperatures of 1000°–2300°F. (540°–1260°C.) is compared with that of thermocouples of previously known types.

BRITISH DRIVER-HARRIS CO., LTD.
Brit. Pat. 783,817 (Similar to *Australian Pat.* 204,673)
(„ „ *French Pat.* 1,128,809)
(„ „ *S. African Pat.* 2227/55)

Nickel-base Hardfacing Alloys

Hardfacing alloys of nickel base and containing silicon and boron are claimed, in *Brit. Pat.* 785,416, as being particularly suitable for application to stainless steel and to molybdenum. The present patent modifies such alloys by addition of chromium and iron: the chromium increases oxidation-resistance and both elements raise the hardness of the micro-constituents of the alloy. Composition limits are silicon 2·5–5·5, boron 0·75–5·25, chromium 4–9·5, iron 1–5, per cent., balance nickel. It is specified that the chromium+iron content shall be not less than 5 and not more than 12 per cent., and that the iron constituent shall always be less than the chromium. It is claimed that such alloys are especially suitable for hardfacing at relatively low temperature.

COAST METALS, INC.
(inventor, A. T. CAPE). *Brit. Pat.* 789,277.

Refractory Materials for Coating and Bonding Metals

Pastes suitable for applying to or between metal parts, to form a heat-resisting coating or a heat-resisting bonding layer, consist of a refractory medium having high electrical-insulating properties. A refractory coating specified in this patent consists of an acid phosphoric binder, a chromic-acid-action inhibitor and a powdered refractory filler. It is claimed that good bond strength is obtained with such materials, that maximum inhibition of acid attack on the metals is obtained, and that the baking cycle required in application of the paste is relatively non-critical.

BRISTOL AERO ENGINES, LTD.
(inventors, R. W. ARCHDALE and G. J. FAULKNER).
Brit. Pat. 790,117.

Coating of High-Temperature Nickel Alloys with Aluminium

Inconel or other alloys may be coated with an impermeable deposit of aluminium by wetting the surface with molten aluminium in presence of a chloride-base fluxing agent carried in suspension in a suitable liquid vehicle. Examples of flux compositions are given.

The part is sprayed with the mixture and the slip is dried. The coated part is then baked, to cause the flux and the aluminium powder to melt and the aluminium to alloy with the basis metal. After cooling, the flux residue can be removed by hot-water washing, and a passivating treatment is carried out in nitric acid, giving a clean white surface. The resultant coating consists of an inner phase of diffused aluminium or aluminium alloy in solid solution with the basis metal, and a surface phase of pure aluminium or aluminium alloy which contains at most only a trace of the fluxing agent. Subsequent heat-treatment at 1500°–1750°F. (815°–955°C.) may be applied to enhance corrosion-resistance, by causing further diffusion of the aluminium into the basis metal and by improving the adhesion of the outer layer.

SOLAR AIRCRAFT CO. *Brit. Pat.* 791,502.

Cladding of Steel with Molybdenum-containing Nickel-base Alloys

Using the sealed-pack rolling process, steel can be clad with alloys containing substantial amounts of molybdenum provided that the alloys are of nickel base (e.g., of the 'Hastelloy' type), and that the assembly is heated, prior to rolling, in the presence of an inert or reducing gas, e.g., argon or hydrogen. Typical compositions for the cladding alloys are cited, falling within the range molybdenum 15–35, nickel 50–70, chromium 0–20, tungsten 0–5, per cent. Bonding may be improved by interposition, between the base and the cladding, of one or more layers of nickel or 'Monel'.

PHOENIX-RHEINROHR A.G. *Brit. Pat.* 791,537.

Chromizing of Nickel-containing Alloys

A proportion of the chromium which penetrates into the surface layers of 'chromized' materials forms, at high temperatures, a solid solution with iron and/or nickel. When the temperature subsequently falls the chromium tends to precipitate on the surface of the treated material, in the form of compounds which produce hard but brittle areas liable to scale off under the effect of variations in temperature. Such change impairs properties. According to the invention covered by this patent, resistance of the 'chromized' parts to corrosion and fatigue is improved by preventing formation of this brittle surface precipitate.

This is achieved by a two-stage process. 'Chromizing' is first effected by subjecting the alloy to the action of vapours of a chromium halide, causing chromium to diffuse into the outer layers, and the material so treated is afterwards heated in a non-chromizing atmosphere, to cause removal of some of the chromium contained in the surface layers, by diffusion towards the interior. The non-chromizing atmosphere may consist essentially of hydrogen or cracked ammonia.

The methods described are stated to be applicable also to impregnation with chromium mixed with

silicon or aluminium. Among the materials cited as being successfully treated are alloys of the 'Nimonic' nickel-chromium-(cobalt) series.

OFFICE NATIONALE D'ÉTUDES ET DE RECHERCHES (O.N.E.R.A.). *Brit. Pat.* 787,958.

Surface Treatment of Stainless Steels Prior to Drawing

Mechanical working of nickel, chromium, and alloys containing these elements in association with iron, is facilitated by prior treatment in aqueous solutions of oxalic acid containing a reducible sulphur compound and an activator. The oxalate coating serves to absorb and hold a lubricant on the surface during working operations such as drawing, and the sulphide coating probably acts as a lubricant.

According to the invention covered by this patent, a salt of titanium and/or of molybdenum is added to such solutions, to accelerate the coating action. In addition, it is stated that the coatings produced from the modified solutions are heavier and more uniform, and generally adhere better to the metal surface, than those not so modified. When a molybdenum salt is used the coatings probably contain some molybdenum sulphide, which is in itself a lubricant. A typical composition cited is as follows: (g./L.) oxalic acid 50, sodium chloride 20, sodium bifluoride 10, sodium thiosulphate 3, ammonium molybdate 30. From such a solution, operated at 185°F. (85°C.), a dark, adherent and absorbent coating was formed in 4 minutes on chromium-nickel steel, whereas in the absence of the ammonium-molybdate constituent a coating of similar weight was deposited only after 12 minutes' treatment.

PYRENE CO., LTD.
(inventor, N. F. RICKARD). *Brit. Pat.* 789,131.

Age-Hardening Austenitic Nickel-Chromium Steel

A relatively high-carbon, high-phosphorus austenitic steel, age-hardening to a minimum of Rockwell C 32 (and up to C 50 by suitable adjustment of composition), is characterized by strength and good resistance to corrosion at both normal and elevated temperatures. An advantage, due to the higher phosphorus content, is that the solution-treatment temperature need not be above 2200°F. (1205°C.).

Percentage composition limits are: carbon 0·2-less than 0·3, phosphorus 0·15-1 (carbon+phosphorus at least 0·45), manganese 0·5-15, nickel 3-25 (nickel+manganese 12-30), chromium 10-30, silicon up to about 3, sulphur up to about 0·3, together with about 3 per cent. of metal selected from the group consisting of molybdenum and tungsten and about 0·4 per cent. of nitrogen. The balance is iron.

It is noted that the presence of phosphorus in the range chosen necessitates a critical balancing of the elements carbon, nickel, manganese and chromium, in order to ensure that the steel has the requisite minimum age-hardenability. (Tabular data demonstrate the inter-relation of the elements mentioned and its effect on response to thermal hardening.) The preferred treatment is solution heating at about 2300°F. (1260°C.), quenching, and ageing at about 1300°F. (705°C.). Steels of the type described are considered to be specially suitable for applications in which high strength at room temperature is combined with low magnetic permeability; also for use at higher temperatures where hardness and resistance to softening, combined with oxidation and corrosion-resistance, are essential. Typical applications suggested are exhaust valves, valve seats and similar parts, and components in steam power plant and gas turbines.

R. SCHEMPP, P. PAYSON, J. G. Y. CHOW,
assignors to CRUCIBLE STEEL CO. OF AMERICA.
U.S. Pat. 2,799,577.

Austenitic Nickel-Chromium Steels for Superheaters

Increased temperatures and pressures involved in modern superheater operation call for use of austenitic steels. Straight 18-8 chromium-nickel types are inadequate, unless employed in wall thicknesses which are uneconomic, both in fabrication and operation.

This patent claims steels giving good strength and corrosion-resistance at temperatures above 1350°F. (730°C.) and at pressures substantially in excess of 2000 p.s.i. The composition given (*vide infra*) is characterized by minimum use of strategically important elements, and it is claimed that the steels have adequate heat- and corrosion-resistance, hot workability and weldability, together with freedom from impact embrittlement at elevated temperatures. The percentage limits are given as: chromium 14·36-20, nickel 12-18, carbon 0·02-0·15, manganese 0·25-2·5, silicon 0·1-1·03, tantalum or tantalum+niobium 1-3·5, iron balance. Copper and/or molybdenum may also be present, each in amounts up to 3 per cent.

BABCOCK AND WILCOX CO. *Brit. Pat.* 788,468.

Nickel-Chromium Stainless Steel in Wood-Processing Equipment

Steel used in apparatus for leaching sulphide from beechwood contains carbon up to 0·07, chromium 20-27, nickel 20-27, molybdenum 1·5-3, per cent., iron balance.

DEUTSCHE EDELSTAHLWERKE A.G.
(inventors, K. BUNGARDT, H. J. ROCHA, P. SCHIERHOLD).
French Pat. 1,154,772.

Corrigenda

Nickel Bulletin, 1957, vol. 30, No. 11, p. 204.

Table 'Nominal Composition of Nimocast Alloys', carbon content of 'Nimocast 257', *for* '0·8' *read* '0·08' per cent.; silicon content of 'Nimocast 257', *for* '0·04' *read* '0·4' per cent.

Ibid, 1957, vol. 30, No. 12, p. 227.

Left-hand column, 'Complex Hardenable Austenitic Steel: F.V. 520', lines 4 and 5, *for* 'carbon 8·25 max.' *read* 'carbon 0·25 max.'

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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